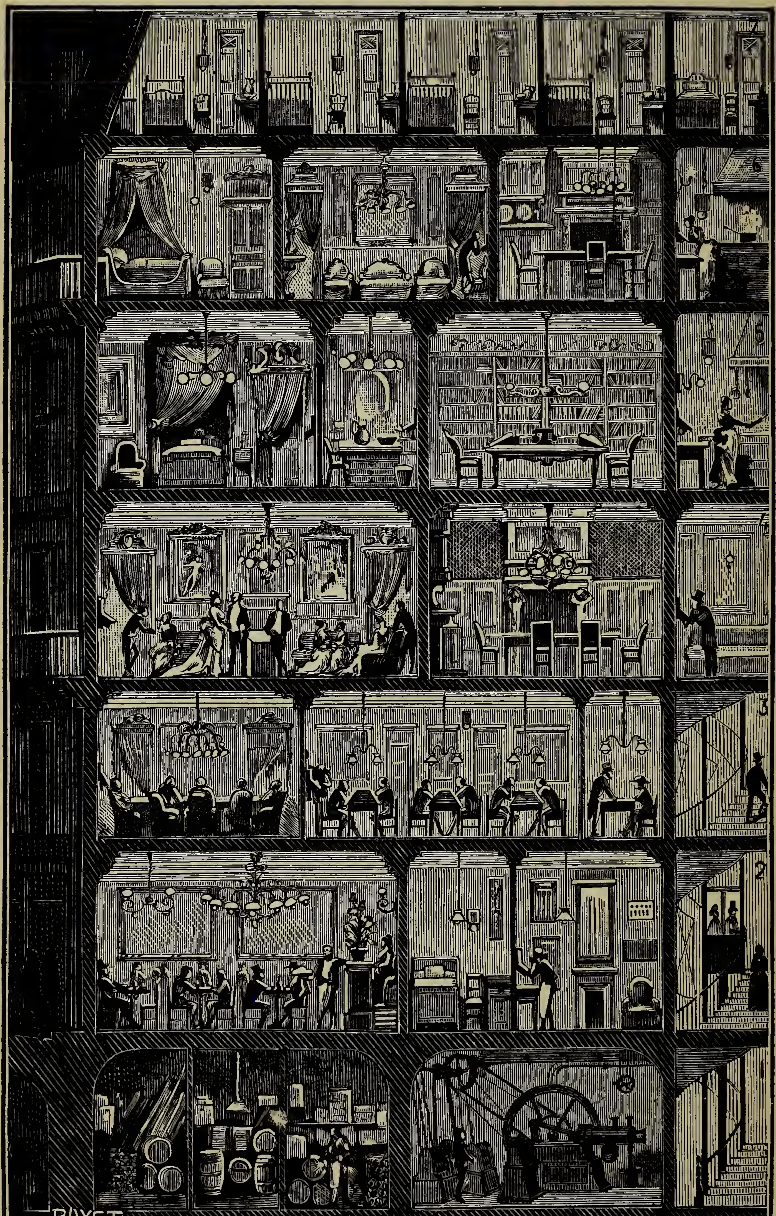
DOMESTIC ELECTRICITY

HOSPITALIER



L. Waldo
Oct. 20. 1885

DOMESTIC ELECTRICITY FOR AMATEURS.

TRANSLATED

FROM THE FRENCH OF E. HOSPITALIER,

EDITOR OF "L'ÉLECTRICIEN,"

WITH ADDITIONS,

BY

C. J. WHARTON,

ASSOCIATE OF THE SOCIETY OF TELEGRAPH ENGINEERS AND ELECTRICIANS.

E. & F. N. SPON, 125, STRAND, LONDON.

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PREFACE.

EVERY one is agreed as to the immense advantages to be obtained from a general distribution of electricity, and it is to be hoped that ere long it may be realised in every city and town, if only on the comparatively small scale at present at work in a few cities of the United States, and on Holborn Viaduct, London.

It will, however, be many years before this distribution can become universal, and although we may look forward to the future with confidence, it is as well to think of the present also, and at the same time to render the public familiar with the numerous advantages to be expected when a general distribution of electricity becomes an accomplished fact, although we can at present only deal with it on a very small scale.

It is for this purpose that the present work has been written, and it must be understood that it is not to the professional electrician that it is addressed, but as its name will imply, it is intended as a book of amusement combined with instruction for the amateur who wishes to know something of the working and uses of that subtle something, "electricity," which, it is prophesied, is destined to revolutionise the world.

LONDON, *May* 1885.

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DOMESTIC ELECTRICITY
FOR AMATEURS.

INTRODUCTION.

LIKE all other physical forces, electricity only reveals itself to us by its effects; we know how to use these effects, to apply them to our requirements, and to measure their magnitude, but the cause which creates them is unknown to us. We will not here endeavour to gloss over our ignorance by erroneous and often deceptive theories, but let us be content with results: for these results are sufficiently interesting and curious to enable us to forget the obscurity which hides their origin.

Beyond all hypothesis, electricity is to us a vague term, under which a series of phenomena and physical actions are understood which are called electrical phenomena. Electricity is no more a fluid than the other physical forces into which it may be transformed, or which give rise to it, such as: heat, light, mechanical and chemical energy. It is, to employ the striking expression used by Professor Tyndall, a peculiar *mode of motion* capable of reproducing, under certain given conditions, every other mode of motion.

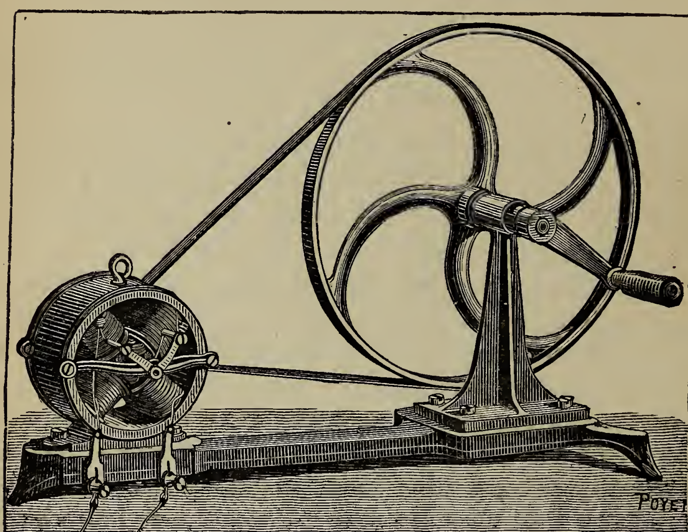
We will first of all make these mutual transformations evident by means of an electric generator, well adapted for this demonstration, but, without for the moment troubling ourselves with its exact constitution, we will consider it solely as an apparatus capable of producing electrical phenomena by the turning of a handle (Fig. 1).

This little machine enables us to make most of the elementary experiments we shall require to demonstrate the case

with which the different phases and applications of electricity and its different transformations are effected.

The first, the most striking, is made with the machine alone, without accessories. It shows clearly the transformation of mechanical into electrical energy. As long as the circuit is open, putting the machine in motion requires but trifling exertion, just sufficient to overcome the friction of the parts.

Fig. 1.



When the circuit is closed by joining the two terminals by a conductor a considerable resistance is experienced, and the operator is compelled to slacken the speed.

The magnetic actions of the current are shown by means of a small compass, Fig. 2, No. 7, which, placed above or below the wire, tends to set itself at right angles with the current. The principle of the electric telegraph is made evident by a vertical electro-magnet, No. 3, magnetised by the current from the machine, and a commutator key introduced in the circuit, which may be worked as desired to produce Morse signals.

For the calorific effects of the current, a small Swan

incandescent lamp, No. 12, is used, mounted on a suitable support, or small clips, No. 4, which enable fine platinum or

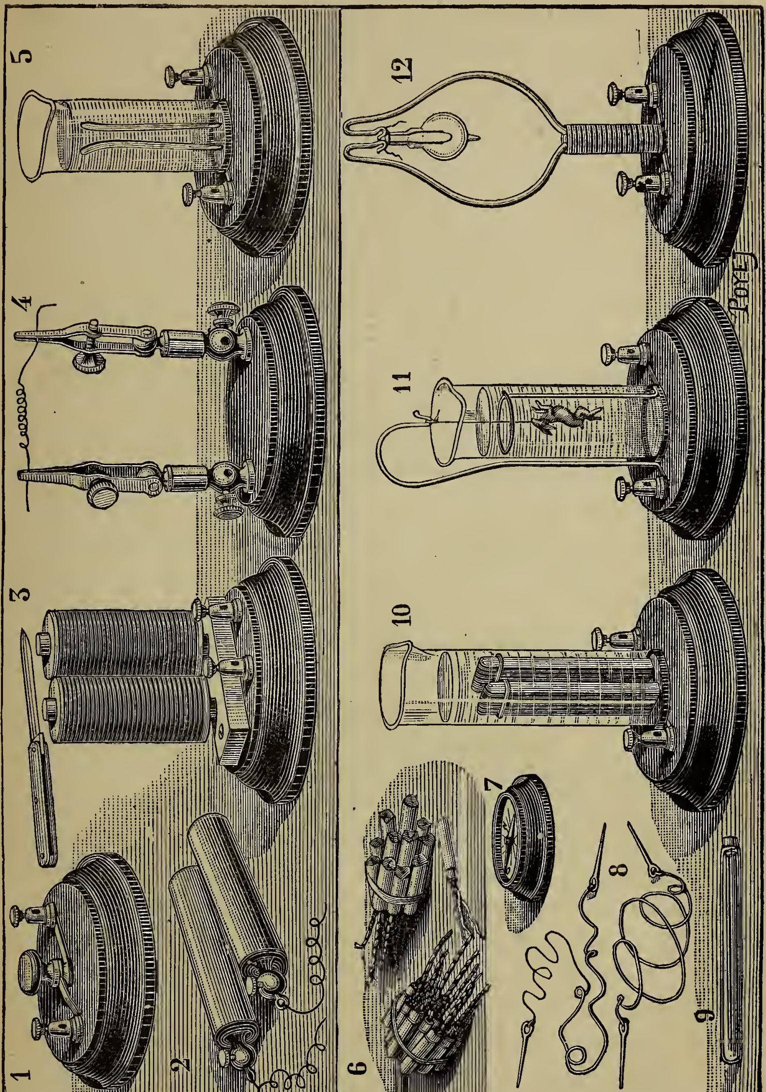


Fig. 2.

iron wire to be heated to redness, and volatilise or to render incandescent small carbon pencils, No. 9.

By simply varying the speed of the machine, the degree of incandescence of the lamp or the wires may be varied. Under calorific effects must also be included the small fuzes, No. 6, which the current explodes when the circuit is completed.

The storage of electrical energy in chemical form is effected by the aid of a small Planté accumulator, No. 10, in which the plates are each formed of a sheet of lead rolled on itself to increase the surface. This accumulator charged by the machine can then set the magnet at work, make wire glow, &c. A voltameter of platinum plates, No. 5, and baths for nickel or silver plating and electro-deposition complete the materials required to demonstrate the chemical actions of the current.

Handles of copper silvered over, No. 2, may be used to give shocks and to show the physiological effects of the current, which can be modified at will by varying the speed of the machine. The shocks are produced here by the extra currents, and in order to obtain them it is necessary to arrange the commutator between the terminals and to complete and open the circuit in rapid succession, or to touch the handles together and then separate them.

These small accessories can be varied indefinitely; let us add: a bell, a small motor, an induction coil, a few Geissler's tubes, a solenoid, a galvanometer, &c.

In all the experiments with the small generating machine we are always obliged to join the two terminals of the machine by something, and that something we name a conductor. This conductor is the seat of all the various phenomena caused by the passage of what we call the electric current; but as before stated, it is not the purpose of this work to investigate the cause and nature of that current; suffice it for us to examine its effects when we have produced it in any of the known ways.

In order to obtain a tangible idea of this electric current, it is convenient to assimilate it to an actual flow in the conductor, and to compare this supposed flow to the flow of water in a pipe. This is, we repeat, merely a conventional notion, but is universally adopted to assist the ideas.

This being admitted, as also that water only flows when there is a difference of level or pressure, and that the flow is from the highest to the lowest level or pressure, so we will suppose the electric current to flow from the highest to the lowest pressure or *potential* as it is usually termed.

This hypothetical and imaginary current then starts from a point where the electric level or potential is highest—or the *positive pole*—to the point where the potential or electric level is lowest—or the *negative pole.*

In all the ordinary batteries the negative pole is always the zinc plate, the positive pole is the other, whether copper, carbon, or platinum. When the two poles are united by a conductor, the electric current goes from the + pole (copper, carbon, or platinum) to the − pole through the conductor.

Continuing our comparison between the electric current and the flow of water in a pipe, we can define and materialise in some way the three most important factors in this circulation.

In a flow of water we have to consider the pressure or difference of level by reason of which the fall is produced; the delivery of the pipe, expressed by the number of gallons of water which pass in a given time, and finally the friction of the pipe which opposes the flow and tends to diminish the delivery.

In the same way, in an electric current, the difference of potential between two given points of a circuit is equal to the difference of the level in the water. The *electromotive force* is the cause which produces this potential difference.

The *current* represents the output of the pipe, and the resistance of the conductor is the obstacle which it opposes to the passage of the current; this is a factor analogous to the friction in the water-pipe.

It will easily be understood that the current will be the greater the higher the pressure and the less the resistance opposed by the conductor to the passage of the current.

These relations between the three electrical measurements, *electromotive force*, *resistance*, and *current*, are expressed by the aid of a very simple law propounded by Ohm in 1827.

This law, known as Ohm's law, is expressed by the following very simple formula :

$$C = \frac{E}{R}.$$

It expresses that the current (C) in an electric circuit is proportional to the electromotive force (E), and inversely proportional to the resistance of the circuit (R).

Electrical Units.

In order to turn this simple relation between the three principal electric measurements to account, a common measure is necessary for the purpose of comparison.

The electrical measurements at present universally recognised and adopted are those fixed by the International Congress of Electricians held at Paris in 1881, and by the International Commission of 1884. The entire system of electrical units is called the C.G.S. system, which recalls its origin as it is based on the three fundamental units, viz. the *centimetre*, as unit of length, the *gramme* as unit of mass, and the *second* as unit of time.

We shall not now demonstrate the relation of all the electrical units one to another and to the fundamental units, but it will suffice for us that the Congress and the Commission fixed the practical units of measurement as well as their names.

Unit of Electromotive Force.—The practical unit of electromotive force, usually written E.M.F., is the volt. An idea of the volt is easily obtained by comparing it with known batteries. The electromotive force of a Daniell cell is about 1 volt; of a newly charged Leclanché 1·48 volt; of a Bunsen from 1·8 to 1·9 volts; of a Planté accumulator from 1·9 to 2 volts.

Unit of Resistance.—The practical unit of resistance is the ohm. This is the resistance at 0° C. of a column of mercury of one square millimetre in section and 106 centimetres in length. A copper wire 48 metres long and one millimetre diameter has 1 ohm resistance. About 100 metres of iron wire 4 millimetres in diameter go to one ohm.

Unit of Current.—The practical unit of current is the ampère. This is the current which traverses a circuit of 1 ohm resistance, with a difference of potential of 1 volt between its two ends, thus :

$$1 \text{ ampère} = 1 \frac{\text{volt}}{\text{ohm}}.$$

Ordinary bells require about a quarter of an ampère ; incandescent lamps require from 0·8 to 2 ampères ; arc lamps require according to their power from 5 to 120 ampères ; the large Edison machines for lighting produce up to 1000 ampères ; and some machines for plating purposes give up to 3000 ampères.

On the other hand telephone currents are calculated by milli-ampères.

Electric Quantity and Unit of Quantity.—If through a pipe water flows during a certain time, the quantity of water which has passed is proportional to the delivery of the pipe and to the time.

In the same way, when a current C traverses a conductor during a time t, the quantity Q which traverses the conductor is proportional to the product Ct. Thus the idea of electric quantity and the definition of the unit of quantity are arrived at.

The practical unit of quantity is the *coulomb.* This is the quantity of electricity which traverses a conductor during a second when the current is one ampère.

The law of Faraday shows the relationship between Q, C, and t, and is written :

$$Q = Ct.$$

It gives for the practical unit of quantity :

$$1 \text{ coulomb} = 1 \text{ ampère} \times 1 \text{ second}.$$

Practical engineers have adopted another unit of quantity directly derived from the coulomb, the *ampère-hour.* The ampère-hour is the quantity of electricity which traverses a conductor in one hour, or 3600 seconds, when the current is

1 ampère, that is to say when one coulomb per second flows through the conductor.

From this definition it results that:

$$1 \text{ ampère-hour} = 3600 \text{ coulombs}.$$

These general ideas are sufficient for the amateur electrician to solve the simple calculations which he will require, and they will become clearer as we advance.

CHAPTER I.

PRODUCTION OF THE ELECTRIC CURRENT.

BEFORE passing in review the different applications to which electricity, or more correctly electrical energy, easily lends itself, we must learn to produce this electrical energy.

The agencies which enable us to produce it reduce themselves to three :

Chemical action as utilised in primary batteries;

Thermo-electric action as utilised in thermopiles ;

Mechanical action as utilised in the machines incorrectly called static and in magneto and dynamo-electric machines.

Thermopiles have not yet arrived at a sufficient degree of perfection to enter into practice, and are in fact of no use to the amateur electrician ; static or frictional machines are only useful for scientific or amusing experiments; we shall later on have a few words to say respecting these latter. Magneto and dynamo-electric machines require a motive power rarely at the amateur's command.

We have therefore only primary batteries left, which are up to the present the only practical generators generally available for the amateur electrician.

Taking into account the uses to which they are applied, primary batteries may be divided into two perfectly distinct classes: one intended for applications which require but small electrical powers, the others requiring greater power and constancy. We distinguish them, to fix the idea in the mind, as batteries for intermittent use, and batteries for continuous use.

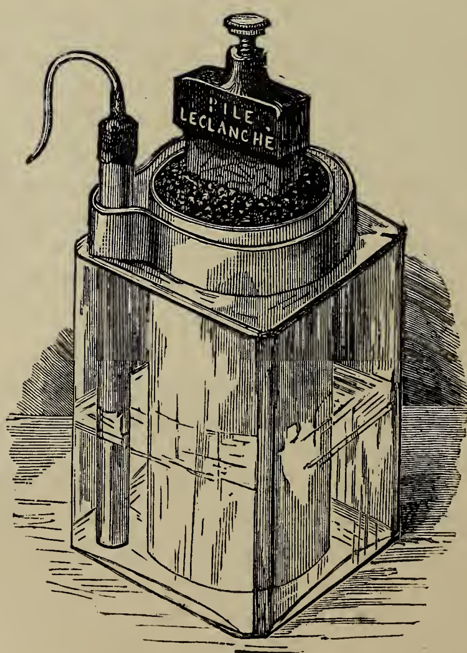
I. Batteries for Intermittent Use.

Batteries for intermittent use are more especially applicable to bells, alarms, domestic telephones, gas-lighters, and for certain amusing experiments which we will describe in due course.

The essential qualities for these various applications are the following: cheapness; erection, maintenance, and supervision easy; long durability; absence of all local action on open circuit; not to be obliged to renew the active elements too often; and, finally, sufficient power to satisfy the demands of the various apparatus required to be operated.

The best battery of this description is no doubt the Leclanché in one or other of its forms.

Fig. 3.

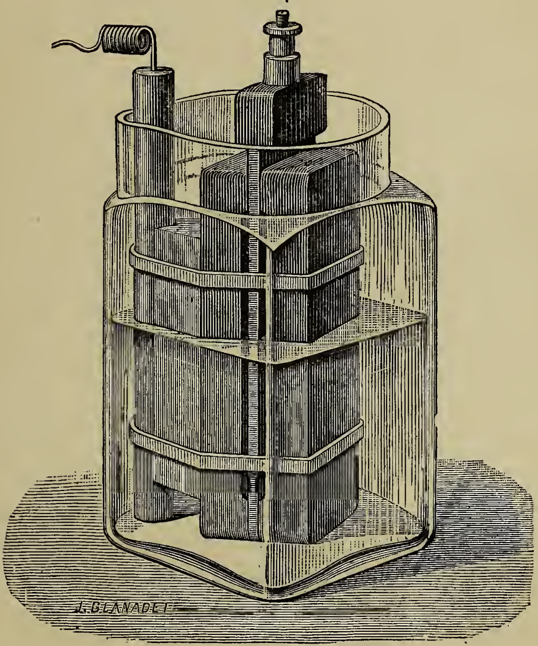


Porous-pot Leclanché.—This element is composed of a block of carbon surrounded by a mixture of powdered carbon and

black oxide of manganese inclosed in a cylindrical porous pot. The negative pole is a rod of amalgamated zinc standing in an exterior glass jar partly filled with a solution of sal-ammoniac (Fig. 3).

Agglomerate Leclanché.—The mixture of carbon and oxide of manganese is here replaced by blocks of the mixture compressed into the solid form in heated steel moulds (Fig. 4).

Fig. 4.



The Leclanché cell, whether of the porous pot or agglomerate form, is perhaps the most useful cell known for intermittent work, although it polarises easily and quickly if used continuously on a circuit of low resistance, and is useless for lighting, plating, or other work where a continuous and large current is required.

To insure proper working and duration, it should be remembered that it is advisable :

1. To place the elements in a dry place and medium temperature.

2. To coat the inside of the neck of the glass jar, if it has not already been paraffined, with a coat of oil or tallow for about an inch down, to avoid the creeping of the salts.

3. To take care that the contacts are in good order, and the conducting wires well insulated.

4. If, in consequence of evaporation, the level of the water has fallen too much, to fill up to about two-thirds the height of the jar.

5. When the liquid, which was originally clear, becomes milky, this is a sign that it wants sal ammoniac, and it is necessary to renew it.

6. To scrape off the crystals which sometimes settle on the zincs; this is the result of an excess of sal-ammoniac.

Duration of Leclanché Batteries.—It is impossible to estimate by time only the duration of Leclanché elements, or, in fact, of any battery whatsoever. A battery, newly charged, represents a certain supply of combustible, zinc, and a certain supply of an oxidiser, which, in this case, is represented partly by the sal-ammoniac and partly by the oxygen contained in the black oxide of manganese.

As soon as one of these bodies—zinc, sal-ammoniac, or manganese—is exhausted, the battery ceases to act, and it is necessary to renew the stock; that is to say, to recharge the battery, by replacing the zinc, the solution, or the agglomerate. For example, let us suppose that the stock of sal-ammoniac is sufficient to furnish an amount of electricity equal to 25,000 coulombs, and that the battery is used solely for domestic bells requiring 0·25 ampère. The bells expend a quarter of a coulomb per second; the battery can therefore act for a duration of

$$25{,}000 \times 4 = 100{,}000 \text{ seconds.}$$

If we make on an average 25 calls per day of 4 seconds each, we expend exactly 1 coulomb per call, and 25 coulombs per day; the battery acts therefore for 1000 days, that is to say, nearly three years. If we make 100 calls per day, the charge will be exhausted at the end of eight months; but in any case, when the total duration of action amounts to

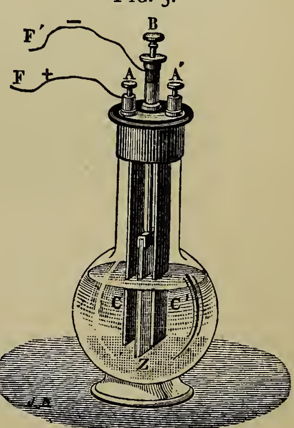
100,000 seconds, or, more correctly, when the battery has supplied 25,000 coulombs of electricity, it will cease to act.

If the wires are badly insulated, so that leakage ensues, the battery may be slowly exhausted in a continuous way without the corresponding useful work being effected, and this is a frequent cause of failure of the battery. When the wires are badly insulated, the only sure remedy is to put the whole of the wires up afresh, taking every precaution and care.

Dry Batteries.—To avoid the inconvenience of the liquids, many people have thought to make dry batteries by filling the cells up with asbestos, sand, or other spongy substance to soak up the liquid, but we cannot recommend these batteries for general use, for several reasons. The presence of inert substances in the cells increases their internal resistance while decreasing the bulk of the active liquid ; and also this inert matter hinders the circulation of the solutions and the renewal of the parts in direct contact with the electrodes, which makes polarisation set in more quickly.

Bichromate of Potash Batteries.—In order to obtain intermittent efforts of short duration and great power, the bichromate of potash battery, either single or double fluid, is the most convenient and most powerful.

Fig. 5.



When a fairly powerful current is required only for a few minutes, the bottle form is very convenient, see Fig. 5.

They are made in all sizes from half a pint to a gallon, or more. In principle it is composed of an amalgamated zinc plate placed between two carbons.

This zinc plate is suspended by a rod of brass, which moves up and down, fitting tightly in a spring socket, and can be lowered into the liquid or withdrawn at will.

The exciting liquid is composed of bichromate of potash,

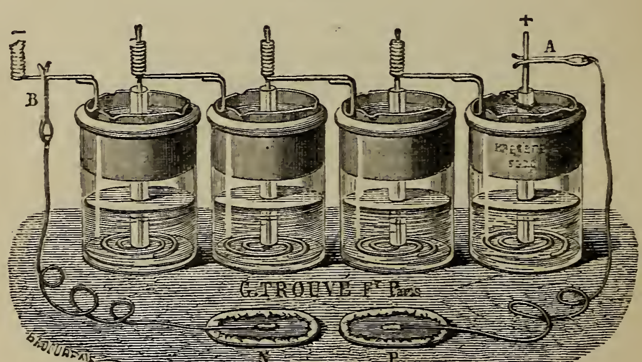
dissolved in sulphuric acid and water (for preparation of the solution, see page 93).

Batteries for Continuous Use.—When batteries are required for continuous work, as for instance for plating, domestic electric lighting, charging accumulators, &c., it is necessary that they possess special qualities very difficult to unite in the same apparatus.

One of the oldest batteries is the Daniell cell, so well known that it appears unnecessary to describe it.

Callaud's Battery.—This form of Daniell, which is much used, is one in which the solution of sulphate of copper is separated from the sulphate of zinc solution, by reason of the difference of density between the two solutions. The form we give (Fig. 6) is very simple, and in consequence

FIG. 6.



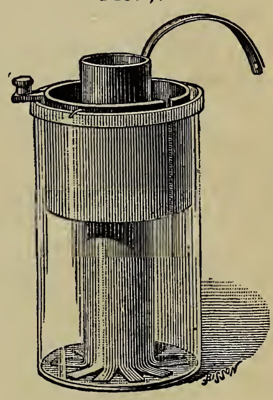
cheap. The glass vessel is about 5 inches in height and 3 in diameter. The zinc is supported by three projections or lips made with a pair of pliers. The copper pole is a flat spiral of copper wire, the end of which rises vertically through the middle of the vessel; this vertical part is protected by a small glass tube. The elements are joined up by means of a small spiral at the end of the wire soldered to the zinc, into which the copper of the nest cell is inserted.

The worst of Daniell cells is that they run down when on open circuit.

Modified Callaud Battery.—This is easier to maintain and has less local action. It is in use in the telegraphic service of the Eastern Railway Company of France, and may be useful to amateur electricians for plating purposes, and for the slow charge of small accumulators.

This battery differs from the foregoing by replacing the positive electrode, that is to say the copper plate, by a lead pipe open at both ends and plunged into the liquid of the battery as shown in the figure. The lead, which is not attacked, lasts indefinitely; it is kept in its vertical position by the lower end being slit up, and the tongues, so formed, spread out; these tongues also serve to prevent the lead tube from touching the zinc.

Fig. 7.



To charge the element, the lead tube is filled with crystals of sulphate of copper, and water is poured into the glass vessel until it is within about half an inch of the top of the zinc. At the end of an hour the sulphate of copper crystals have sufficiently dissolved to enable the battery to act.

Experience has shown that whatever supply of sulphate is put into the lead tube the sulphate solution never reaches the zinc, even when the circuit is open.

This arrangement has the great advantage that it may be given into anybody's charge, since the only thing necessary is merely to replenish the central tube with sulphate of copper crystals when the blue tint of the lower liquid disappears, and to proportion the expenditure to the work actually done.

Lalande & Chaperon's Oxide of Copper Batteries.—These batteries to a certain extent combine the duration of the Leclanché with the power of the bichromate of potash.

They vary in shape and size according to the purposes for which they are intended. In principle they always consist of a plate or cylinder of amalgamated zinc as active metal, a solution of 30 or 40 per cent. of caustic potash as exciting

liquid, and oxide of copper in direct contact with a plate of iron or copper as depolariser.

Owing to the choice of materials, the battery will work on a continuously closed circuit for several days, without excessive polarisation, and almost up to complete exhaustion of the products: the transformation of the potash into oxide of zinc, and the progressive reduction of the copper oxide, act without the constants varying sensibly. The initial E.M.F. some hours after setting up the elements is somewhat less than 1 volt; when in continuous use, it is about 0·85 volts, at which it is maintained.

The internal resistance varies with the dimensions of the elements: its duration depends on the current taken out and the quantity of the active materials, zinc, caustic potash, and oxide of copper, contained in the element at the time of setting up.

Fig. 8.

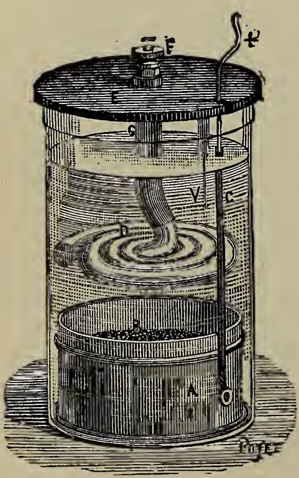


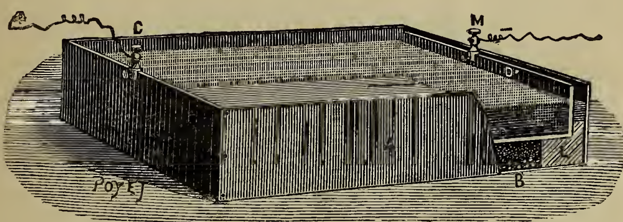
Fig. 8 represents the spiral elements intended for applications which require a small current, as for instance, for telegraph or telephone purposes. It is about 7 inches high and 4 inches diameter, and can supply 200,000 coulombs, or 55 ampère-hours, with a delivery which, for this type of element, should not exceed half an ampère.

The heavy current cell, Fig. 9, is in the form of a rectangular trough of sheet iron, which serves at the same time as containing-vessel and pole. The bottom of the trough is covered with oxide of copper, and the amalgamated zinc plate is placed horizontally over the oxide, resting on four cement supports fixed in the corners. A layer of heavy petroleum over the solution insures the closing up of the element, and keeps the potash from the action of the air.

The small model is 10 inches long, $5\frac{1}{2}$ inches wide, and

4 inches in depth. It can give 6 ampères, and furnishes about 800,000 coulombs, which corresponds to a deposit of 250 grammes of copper. The large model is 16 inches long, 8 inches wide, and 4 inches in depth. Its delivery is 15 to 18 ampères, and it can supply 1,800,000 coulombs of electricity,

FIG. 9.



which is equal to 500 ampère-hours. This cell is supposed to supply at will 1 ampère during 500 hours, 10 ampères during 50 hours, or 15 ampères during 33 hours.

They are suitable for all applications where a Bunsen battery is employed, if every quart Bunsen be replaced by two of these in tension in order to have the same electromotive force.

They can be used for electric lighting by arc or incandescence, for big induction coils, plating, charging accumulators, &c. They have the advantage over the Bunsen elements, inasmuch as they give off no injurious or disagreeable fumes. They act without attention until exhausted, and above all, have the essential quality of practically consuming nothing when the circuit is open.

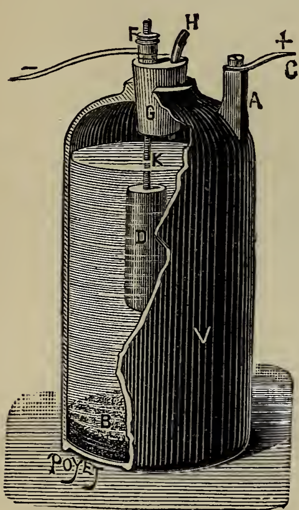
Its disadvantage, however, is that it necessitates the use of the destructive caustic potash, and it is necessary to carefully keep this battery in a place where the accidental upsetting of a cell will have no serious consequences.

Cast-iron Hermetically Closed Cells.—These have the advantage of being easily transported and possessing a great solidity, one of the most important qualities for elements holding a caustic liquid.

In the 4-inch or small current cell, Fig. 10, the exterior

cast-iron case has the appearance of a conical shell. It constitutes the positive pole of the element; a shoulder A in the casting forms the terminal. The exterior of the pot is coated with paraffin, so as to prevent rusting and leakage. The zinc D consists of a cylinder $\frac{3}{4}$ inch in diameter soldered to a brass rod K fixed in the indiarubber stopper G, and carrying the terminal F. The stopper has also passing through it a metallic tube ending in a valve H formed of a bit of soft indiarubber tube.

Fig. 10.



These elements are generally delivered filled with the potash solution, so that in order to set them up, it is sufficient to pour in the proper quantity of copper oxide, which distributes itself on the bottom B, and to close the element up by means of the indiarubber stopper with the zinc fixed.

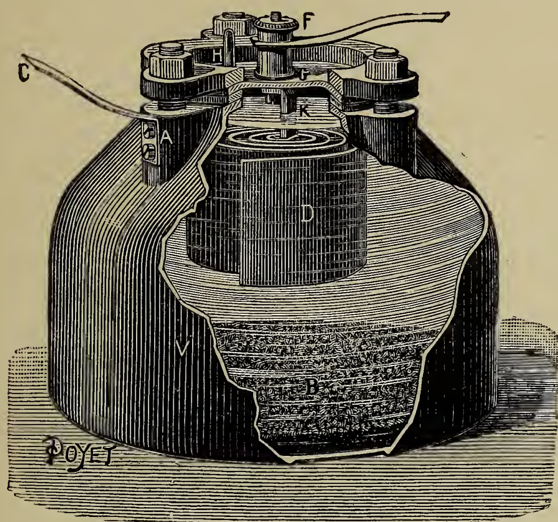
This arrangement is especially convenient for house work, telephones, bells, &c. This model can give as much as 2 ampères. A smaller size of 2 inches in diameter is sufficient for house bells for several years.

Fig. 11 represents another type of the hermetically closed element, intended for larger currents, about 9 inches in diameter, giving up to 8 ampères, which enables it to be used in place of Bunsen or bichromate cells. The arrangement of this element is much the same as the preceding one. The copper oxide B is at the bottom of the pot; the zinc D, made by a long plate rolled in spiral shape to present a great surface, is suspended from an ebony lid G fixed in the mouth of the jar by means of an iron ring and three screws; a soft rubber washer insures the closing of the joints.

These elements hold the same charge as the large trough-cells, and can be substituted for them in all applications.

They can do considerable work ; for example, a trough battery could light for 200 hours a 5-candle Edison lamp. By employing six elements nearly two months of nickel-plating work of seven hours per day has been done, which necessitates the

FIG. 11.



use of three Bunsen elements : these require recharging every two days. These cast-iron cells have the remarkable property of giving a much heavier current without polarisation than corresponding non-metallic elements of which the conducting surface in contact with the copper oxide is as great. As hydrogen is not set free on the iron, the inventors claim that its surface must nevertheless occlude the hydrogen which travels along to the copper oxide, and thus contributes to the depolarising action.

The Conventional Sign for a Battery.—A convenient plan universally adopted represents a battery by the conventional signs shown in Fig. 12. The thick stroke stands for the positive pole, the thin stroke the negative pole, and the number of pairs for the number of elements. Fig. 12, for example, shows a battery of five cells, of which the positive pole is to the left and the negative pole to the right.

Connecting-up Batteries.—Amateurs generally experience much difficulty in not knowing how to couple up a battery, of which they have a given number of elements, so

FIG. 12.

as to obtain through a given resistance the greatest current possible with this given number of cells. There exist methods whereby this coupling up is determined with certainty in each particular case, which we will endeavour to explain, avoiding complicated formulæ, and by giving some practical examples, facilitate their use even to those little accustomed to algebraical calculations.

The determination of the best method of coupling up is governed by three measurements which must be expressed in the electrical units, volts and ohms, before they can be used in formulæ. These measurements are :—

1. The electromotive force of one element E expressed in volts.

2. The internal resistance of this element r, expressed in ohms.

These two quantities, which are called the constants of the battery, are generally supplied by the makers ; they vary with the nature and dimensions of each element.

3. The external resistance R, expressed in ohms.

This resistance comprises not only the resistance of the conductors, but also that of the instruments to be worked.

In the most simple case, where a single cell is placed in the circuit, the current C expressed in ampères is :—

$$C = \frac{E}{r+R}.$$

When several elements are available, they may be coupled up in various ways, for example:—

1. All the cells may be coupled in quantity (otherwise called in parallel or in multiple arc), that is to say, all the zincs joined up to each other in such a way as to make a battery of which the electromotive force is that of a single cell, but of which the internal resistance is as much smaller as the number of elements is greater.

2. All the cells may be coupled up in tension or series, that is to say, the zinc of the first cell coupled to the carbon of the second, the zinc of the second to the carbon of the third, and so on. In this way both the electromotive force and the internal resistance are multiplied at the same time by the number of elements.

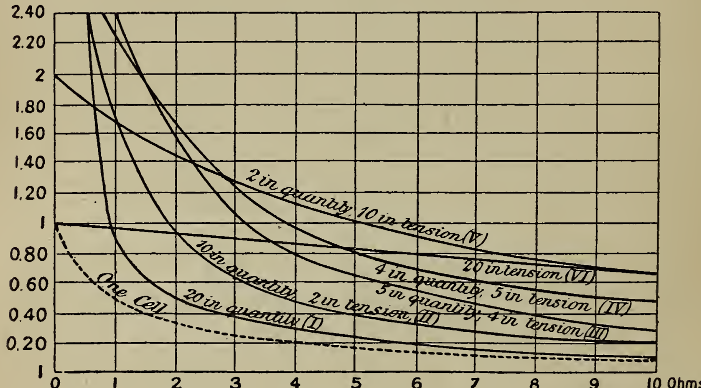
Between these two extremes a middle course is often advisable, which we will explain by example.

Let us suppose we have 20 cells available. These 20 elements enable us to obtain the following 6 combinations: 1st. 20 cells in quantity, and 1 in tension. 2nd. 10 cells in quantity, and 2 in tension. 3rd. 5 cells in quantity, and 4 in tension. 4th. 4 cells in quantity, and 5 in tension. 5th. 2 cells in quantity, and 10 in tension. 6th. 1 cell in quantity, and 20 in tension.

According to the resistance of the external circuit, one or the other of these arrangements will be found most advantageous. The variations of the current when the external resistance is varied may be represented by a curve. Fig. 13 represents these curves, in which the abscissæ are the external resistances in ohms, and the ordinates the corresponding currents in ampères. To simplify the calculations of these curves, we have assumed a battery of which the E.M.F. is exactly 1 volt, and the internal resistance 1 ohm. In practice this corresponds nearly to a large Daniell. By consulting the curves, it is seen, for example, that with an external resistance of 5 ohms, that is to say, five times that of the element, the maximum current is obtained by arranging 10 cells in tension and 2 in quantity, it is therefore 1 ampère. By arranging the 20 elements in quantity, C = 0·22 only is

obtained, not much more than that given by a single cell. A careful study of these curves will give a very good idea of the importance of properly connecting up a battery when the constants, the number of cells, and the external resistance are given, and it will appear generally that quantity arrangement is best for low external resistance and tension for high external resistance. By comparing the dotted curve which corresponds

FIG. 13.



to a single cell with curve No. VI., it will be seen that on a circuit of no resistance 20 elements in tension do not give more current than one. The comparison between the dotted curve and curve I., on the other hand, shows that for great resistances a single element gives as much current as 20 in quantity. The crossing points of these curves indicate the resistance with which it is immaterial whether one or other corresponding arrangement be adopted.

The following are the formulæ by which it is possible to determine the arrangement which gives the maximum external work and the value of the corresponding current:

Let t be the number of elements arranged in tension;
q the number of elements arranged in quantity;
n the total number of elements:

$$\text{then } n = t\,q.$$

The current in an external circuit of a resistance R, if E

is the E.M.F. of one element, and r its internal resistance, will be

$$C = \frac{t\,E}{\frac{t}{q}r + R}. \qquad (a)$$

By varying t and q in such a way that the product $t\,q$ remains constant, there is a maximum for the external work when

$$\frac{t}{q} = \frac{R}{r}. \qquad (b)$$

The external work is a maximum when the number of elements in tension (t) is to the number of elements in quantity (q) as the external resistance (R) is to the resistance of each element (r).

Numerical Example.—What is the best arrangement for a battery of eight Daniells ($E = 1{\cdot}07$ volts, $r = 6$ ohms) to work a bell whose resistance is 10 ohms on a line whose resistance is 4 ohms?

According to the given problem, $R = 10 + 4 = 14$ ohms. The formula (b) gives:—

$$\frac{t}{q} = \frac{14}{6} = 2{\cdot}33.$$

In practice it is necessary to take for t and q, the numbers approaching nearest to this ratio. In this particular case, it is by taking $t = 4$, $q = 2$ that the equation is best satisfied.

Under these conditions, the current calculated by the formula (a) will be:—

$$C = \frac{4 \times 1{\cdot}07}{\frac{4}{2} \times 6 + 14} = \frac{4 \times 1{\cdot}07}{12 + 14}$$

$$C = 0{\cdot}16 \text{ ampère.}$$

By coupling up the 8 cells in tension $t = 8$, $q = 1$ the formula (a) gives:

$$C' = \frac{8 \times 1{\cdot}07}{8 \times 6 + 14} = 0{\cdot}14 \text{ ampère, nearly.}$$

By coupling up the 8 cells in quantity $t = 1$, $q = 8$, the formula (a) gives:—

$$C'' = \frac{1{\cdot}07}{\frac{6}{8} + 14} = 0{\cdot}07 \text{ ampère.}$$

It will be seen that the latter method gives a current less than half the maximum.

When the constants of the batteries, the number of elements at disposal, and the resistance of the external circuit are known, formulæ (*a*) and (*b*) enable us to determine the ratio between t and q, which gives C a maximum, and to calculate exactly the value of this current corresponding to each particular coupling up of the cells.

In conclusion we give some practical figures respecting the batteries mostly employed for domestic purposes which may serve as a guide when electric bells, lighters, &c., are required to be installed.

The porous pot Leclanché has an E.M.F. of 1·4 volt and an internal resistance of about 5 ohms. The new agglomerate Leclanchés have the same E.M.F., but the internal resistance is only 1·2 ohm. After long use the E.M.F. falls to 1 volt and the internal resistance attains 2·5 ohms.

Daniell elements have an E.M.F. of 1·07 volt. Their resistance varies much with their dimensions. The large circular cells 8-inches high have 3 ohms resistance; those used for telegraph purposes vary between 5 and 20 ohms.

The Bunsen battery has an E.M.F. of 1·8 volt; the circular cell 8-inches high has a resistance of 0·25 ohm.

Niaudet's battery has for constants $E = 1$, $r = 5$.

The bichromate of potash battery has an E.M.F. of 2 volts when fresh charged; the quart bottle battery has a resistance of about 1 ohm.

These figures are only approximate, especially those relating to internal resistance, which varies greatly with the degree of saturation of the liquids, the surface of the plates, their distance, &c., but in any case they serve as a guide, and may prevent grave errors.

The currents required vary greatly according to the nature of the appliances.

Keeping ourselves to domestic appliances and telegraphs, we give some figures, the results of experience.

The bichromate gas-lighters act with currents which vary between one ampère and one-tenth of an ampère, according to the size of the incandescent spirals.

Domestic bells act very well with two Leclanché cells in tension ; the resistance of the wires does not exceed 2 ohms, that of the bells varies between 5 and 10 ohms.

Under average conditions the current is therefore :—

$$C = \frac{2 \times 1 \cdot 4}{2 \times 1 \cdot 2 + 10} = 0 \cdot 23 \text{ ampère.}$$

Polarisation, bad contacts, &c., reduce this to 0·20 ampère or 200 milliampères.

Telegraphic currents under ordinary circumstances are not more than 10 milliampères, which is twenty times less. The attraction on the armature is, however, the same in both cases. This difference is thus explained: in domestic bells the proportionately large wire takes a small number of turns round the electro-magnet, whilst in telegraphic apparatus the number of turns is much greater. The attractive power depending on these two factors, what is gained in current is lost in the less number of turns, and besides, the electro-magnets of domestic bells are used on comparatively short circuits, while the electro-magnets of telegraphs are included in a long circuit of great resistance.

It is therefore necessary before connecting a battery for a given instrument, to know exactly its resistance and the current necessary to enable it to act properly.

The formula (*a*) will give the number of cells of a battery of which the constants E and r are known, necessary to produce a current C in the circuit of the apparatus, for by combining it with formula (*b*) a double equation will be formed of two unknown quantities easily solved. In fact, the formulæ (*a*) and (*b*) give t and q; the value of n will then be the product, provided we take t and q as the whole number nearest to the exact value, it being impossible to divide into fractions the cells of a battery. In case the number of elements n is determined beforehand, the formula (*b*) will give the arrangement which gives the maximum current, and the formula (*a*) will give the value of this current. It will then be seen if it is more or less than that required by the apparatus in order to work properly.

CHAPTER II.

ELECTRIC BELLS.

THE most simple and practical application to which the amateur electrician can direct his first knowledge and obtain tangible results is without doubt the installation of electric bells in a room or house. We will therefore commence with them, describing all the necessary details. Reduced to its most simple character the system always includes at least four essentials: the electric generator, which here will always consist of a battery; properly insulated conductors; the contact-maker to close the circuit between the battery and the bells; and, finally, the latter themselves. We will review the arrangements employed in ordinary practice.

The Battery.—The Leclanché battery is the most convenient for electric bells. Porous pot elements are sufficient if they are used exclusively for bells; if gas-lighters, fire-alarms, alarum clocks, &c., are wanted to be installed at the same time the agglomerated form is perhaps better. Four cells in tension are sufficient for most cases.

The small Lalande and Chaperon batteries are also good for electric bells; three to four elements in tension are sufficient.

Laying the Conductors.—The conductors placed in interior of houses are usually of copper, covered with an insulating compound such as indiarubber, &c.

For short lines, and in dry places, wire simply covered with silk or cotton may also be used.

The size of the wires necessarily varies with the length of the circuit, the nature of the apparatus to be worked, and the

number of elements to be used. We give some figures which may be taken as the average in practice.

Let us take for example a very usual form of installation, consisting of a battery of three or four cells in the basement or elsewhere, to work the front door and various rooms and floors. Under these circumstances three sizes of wire are used :—

1. Between the battery in the basement and the staircase, wire of $\frac{11}{10}$ mm. should be used. This is about equal to No. 18 B.W.G.

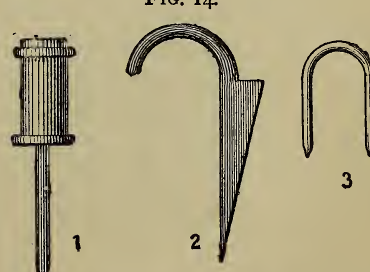
2. In the staircase, wire of $\frac{10}{10}$ or 1 mm., equal to No. 19 or 20 B.W.G.

3. For the interior communication of the apartments, wire of $\frac{9}{10}$ will be quite sufficient, Nos. 21 or 22 B.W.G.

In practice it need never be feared to use wire too large, except for the price. In the case of which we speak, in large towns, half of this wire may be saved by fixing the negative end of the battery to water or gas pipes, in which case all the negative branches from the various bell-pushes, &c., must be taken to the nearest gas or water pipe ; these pipes then act as return wires and simplify the installation.

Wires covered with silk and cotton of all shades may be obtained to match the wall-papers and other furniture. They should be fixed to the walls, avoiding contact as much as possible, especially at sharp corners, which tend to cut the insulation ; they may be concealed in the mouldings, cornices, or corners, or where appearance has to be specially studied, ornamental hollow casing may be laid over them.

FIG. 14.



To keep the wires in position, bone insulators (Fig. 14, No. 1), may be used nailed into the wall, round which a turn is taken with the wire ; for re-entering angles enamelled hooks (Fig. 14, No. 2) of a convenient size are used. Staples (Fig. 14, No. 3) are also used ;

they are easily fixed, and the price very moderate, but care must be used in driving them in not to cut the insulation.

When the wires go through the walls it is important to keep them from dampness; they should then be covered by an indiarubber tube of suitable diameter, drawn out for half-an-inch or so on each side of the wall to keep the wires from contact with the sharp edges of the hole.

The junction of the wires is effected by stripping the two ends to be joined for about two inches, cleaning them with sandpaper and twisting the two ends five or six times over each other.

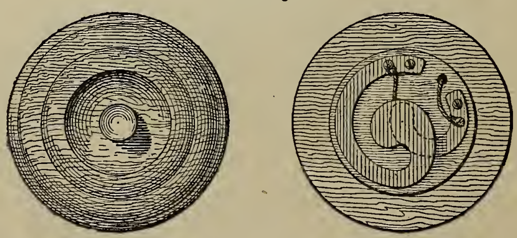
The joint must then be covered by a thin sheet of softened rubber by rolling it between the fingers and then with a layer of cotton similar to that of the rest of the wire. When double wire is used it is advisable not to make the two joints at the same place, but about two inches apart.

It is often convenient to use two wires covered with rubber, inclosed in the same cotton or silk covering.

Joining the wires with the springs of the contact-maker and the terminals of the bells presents no difficulty.

Contact-makers.—Under this general head may be included every device which, by a simple mechanical motion, allows an electric communication to be established. The most simple arrangement for this purpose is the ordinary bell-push (see Fig. 15). It is so well known that we need not describe it;

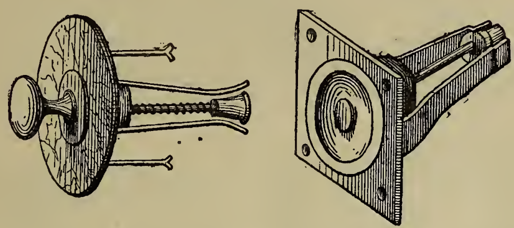
FIG. 15.



it varies in form, size and nature, according to requirement. It is made of wood, ebony, porcelain, bronze, copper, ivory, celluloid, &c. The most simple form may be bought for sixpence. It is simply fixed to a wall, panel, &c., by means

of two wood-screws, taking care to plug the wall previously if necessary. For outside doors pulls or presses are sometimes used, in which the contact arrangement differs, but the method of working will be understood from Fig. 16.

FIG. 16.



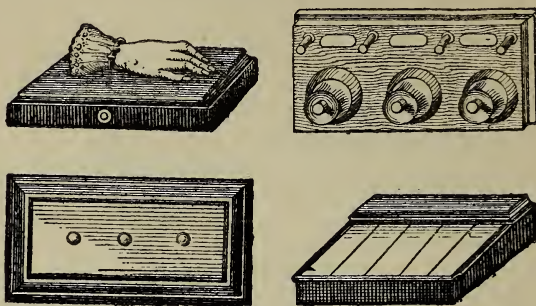
These outdoor contact-makers are more solid and less liable to damage than the ordinary pushes; they are also not so likely to get out of order by oxidation as the contact is a sliding or rubbing one which keeps the surfaces clean.

By a most ingenious and simple device recently patented by Mr. Kenneth D. Mackenzie, the person making the call by pressing the call button may have audible evidence that the bell at the other end of the circuit has really rung. This apparatus may be added to any existing presses, or a special press may be used inclosing the ordinary contact-maker and the sounding apparatus in a neat box, slightly larger than the ordinary button. The sounder consists of a small bobbin included in the line circuit. This bobbin has a soft iron core, and stands in a little round box of tinned iron, the base of the core being screwed to the bottom of the box. The lid is then put on, and is so arranged that though close to the top of the iron core, it is not in contact with it. When the make and break current passes, the core and box are alternately magnetised and demagnetised, producing a vibrating tinkle easily heard. This then gives instant indication to the person ringing that the bell at the other end has actually sounded.

In offices, public institutions, hotels, &c., where it is necessary to call various different persons, multiple contacts are used, of which Fig. 17 shows some specimens. The hand in the form of a paper weight is a multiple contact, and calls

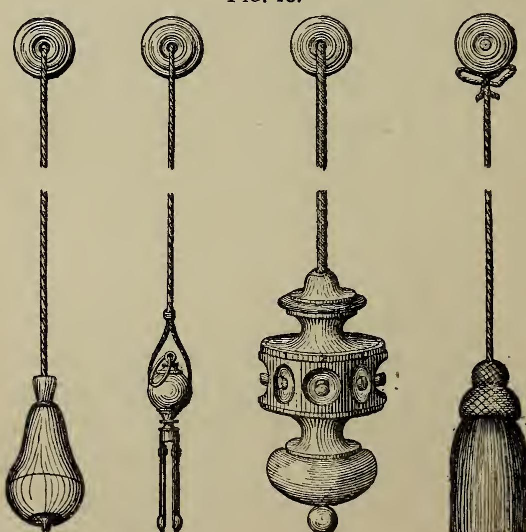
are made by pressing one or other of the bracelet stones. A flexible wire to the various conductors established the necessary communication. It is sometimes more convenient to have a

Fig. 17.



movable push; it is then placed at the end of a flexible cord. Fig. 18 represents some of the means employed.

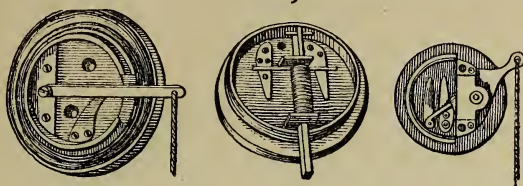
Fig. 18.



No. 4 shows a contact-maker, resembling in use and appearance an ordinary crank bell-pull, the actual electrical contact being made by means of a lever and spring concealed in a

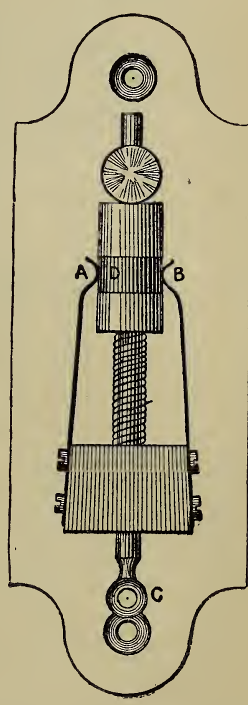
box near the ceiling. The internal arrangements are very various, and Fig. 19 shows some: A and C require a side pull; B, a centre pull.

FIG. 19.



A very ingenious arrangement by Charpentier is one in which the contact acts, not only as an ordinary call, but in case of fire rings the bell continuously. To this end a very light and combustible cord is fixed to the ring C, Fig. 20, holding a weight heavy enough to lower the metallic ring D below the two points A and B. Contact is made by lifting the weight suspended from C, when the spiral spring forces the ring D back, and thus makes contact between the two bent springs as shown in the figure. The advantage of this arrangement is that when the cord which holds the weight burns, the weight falls, the ring D then ascends and establishes a continuous contact, and the bells give the alarm.

FIG. 20.

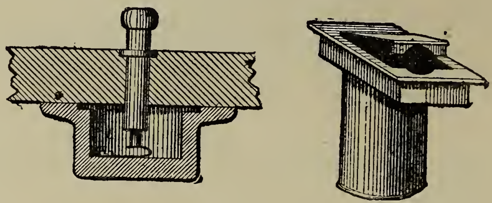


In conclusion we may mention two pedal arrangements for offices or dining rooms, the action of which will be understood from Fig. 21, and the door or window contacts shown in Fig. 22; these latter act automatically on a bell when a door is opened or shut.

The rabbet contact (Fig. 22) breaks the contact when the door is closed, and acts the whole time the door is open, which is sometimes inconvenient, but can be remedied by

introducing a switch into the circuit between the contact and the bells or the battery. The other contact shown in the figure only acts momentarily every time the door is opened or shut. This arrangement is a contact by friction giving great security.

Fig. 21.



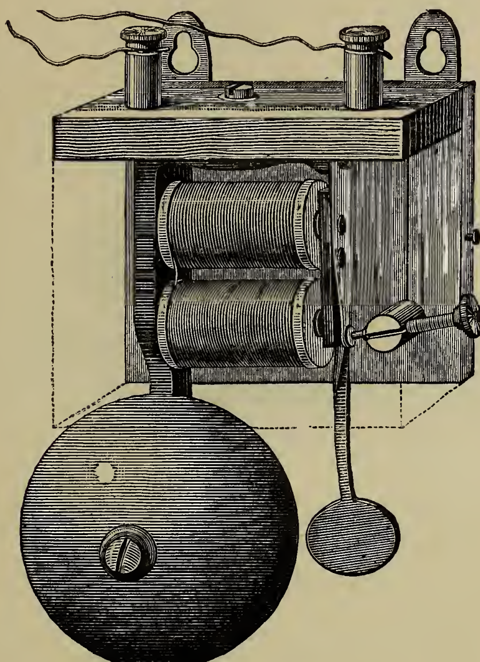
These are the principal contacts employed in practice; their arrangement can be varied indefinitely according to the purpose in view, but what we have said will suffice for most cases with which the amateur is likely to meet.

Fig. 22.

Bells.—Trembling bells are generally used, of which Fig. 23 shows a very simple and cheap model. It is composed of a square-shaped casting, which constitutes the body of the system as it carries the bell, the electro-magnet, the counter-spring, the armature, and the hammer. The interrupter, with its regulating screw, is mounted on a piece of wood, on which is fixed the box which protects the system from dust. The bell is then secured to the wall by means of two hooks and clasps. In the more elaborate, but more expensive arrangements, the support of the regulating contact screw is placed on the same metallic support as the magnet and the bell; the contact screw being fixed by a lock-nut. This arrangement may be used with bells of all sizes of from 2 to 12 inches diameter.

In order to distinguish the bells from each other, and to suit the buyers' tastes, they are made in the form of clock-bells, gongs, or domes of bronze, lignum vitæ, which has a peculiar dull sound, or even of glass.

FIG. 23.



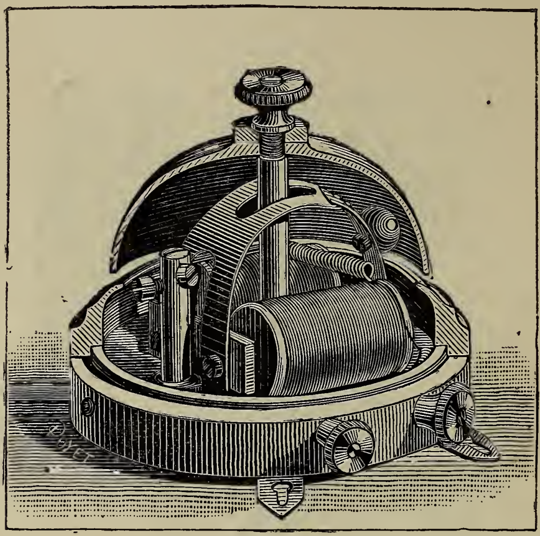
If indicators are not employed the bell is sometimes furnished with an index which falls when the bell has acted, thus indicating the call by a permanent signal when the person to whom the call has been made is absent for a time.

The bell shown in Fig. 24 has been designed to act in all positions, whether flat on a table, against a wall, or on a jolting vehicle. The entire mechanism is arranged in a round case, of which the hemispheric lid is the gong, thus making a very portable apparatus, and neat in appearance.

The electro-magnet is placed at the bottom of the case and acts on an armature fixed to a spring bent round into a

semicircle. A small strip cut out of the spring acts as interrupter, and a brass ball at the other end forms the hammer.

Fig. 24.



Fixing the Bells.—Fig. 25 is a diagram of the most simple installation that can be imagined: a battery P, a contact-button 1, and a bell S.

Fig. 25.

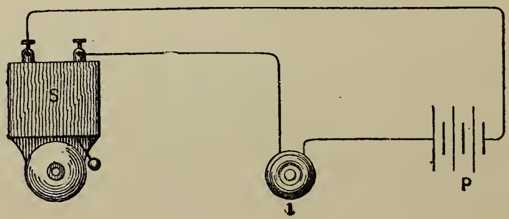
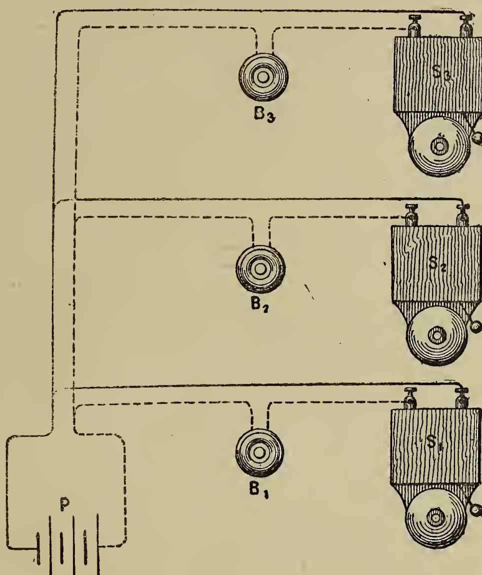


Fig. 26 shows the arrangement of a single battery supplying several bells, acting separately by different buttons.

Fig. 27 represents a battery P, acting on a bell S, put into motion by three different buttons, 1, 2, 3. Where gas is laid on in the apartment, the wire represented by the dotted

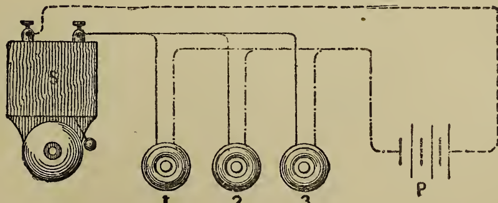
line in the figure can easily be omitted; it will do if the left terminal of the bell S and the negative pole of the battery is joined to the gas-pipe. By means of three wires and the one

FIG. 26.



battery it is possible to fix two buttons and two bells, so that by pressing button 1 (Fig. 28) the bell S_1 alone rings, and

FIG. 27.



button 2 only rings the bell S_2. The diagram will explain the connections.

In certain cases, where only one bell is at disposal, and where it is necessary to make three distinct calls at A, B, and C (Fig. 29), it is easy to use this single bell without an

FIG. 28.

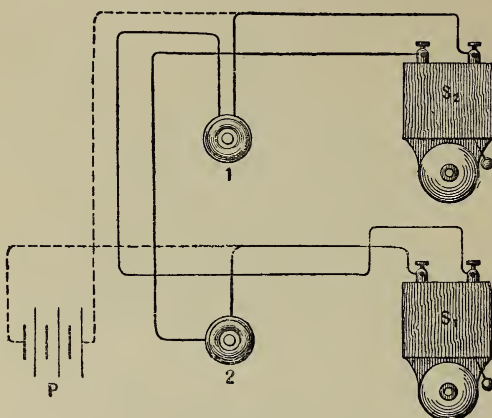
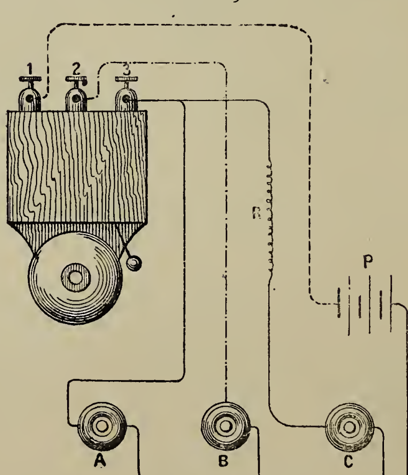


FIG. 29.



indicator, in order to easily distinguish which is the button, A, B, or C, which has called.

For this purpose it is sufficient to use an ordinary bell (Fig. 30), and to add to it a third terminal 2 joined electrically

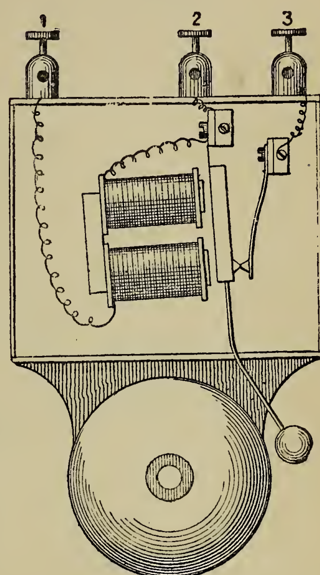
to the support of the armature. The wires are arranged as shown by Fig. 29, taking care to introduce a resistance R of a convenient length between the terminal 3 of the bell and the button C. Three different and well-defined calls can thus be made :—

1. By pressing on A, the sound will be a trembling one of ordinary power.

2. By pressing on B, the armature will be attracted once, and strikes once, and thus we have a single-stroke arrangement.

3. By pressing on C, a sound is heard, weakened by the resistance R, which it will be impossible to confound with that of A.

Fig. 30.



It would be convenient to make B the front-door bell, the ordinary trembling one in the drawing-room or bedroom, and the weakened ring in the dining-room, because, in the last case, when used, the person for whom the call is intended would naturally always be near the bell, and does not consequently require a loud call.

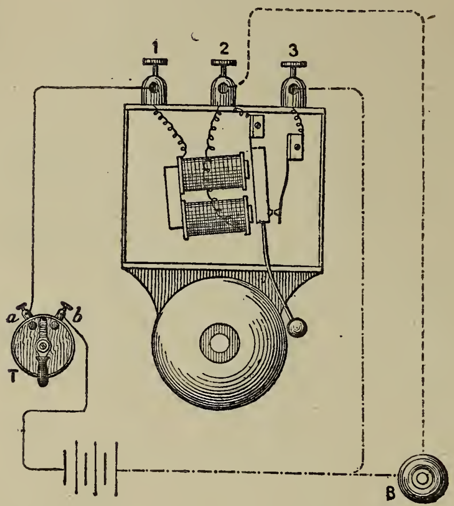
The expense of putting up an indicator-board for these few calls is thus saved.

The three-terminal bell (Fig. 31), somewhat modified in its arrangement, constitutes a continuous bell. Every time the button is pressed, whatever be the duration of the contact, the bell rings continuously until it is stopped by a switch, which in many cases acts as a security and a check.

In order to understand the connections, it will be sufficient to examine Fig. 31. Ordinarily, the switch T interposed between the terminal 1 of the bell and the positive pole of the battery closes the circuit there, but there being no contact between the armature and the spring joined up to the

terminal 3, the bell does not act. By pressing the contact B, the current from the battery passes by 2 and 1, the armature is attracted and remains fast against the electro-magnet; when the pressure on the button is stopped, the armature

FIG. 31.



rebounds, owing to the elasticity of the spring to which it is fixed, with such force that it goes beyond its original position, the two points touch, when a current passes into the electro-magnet by 3 and 1, the armature is attracted, the contact breaks, the armature recoils, re-establishes contact, is attracted again, and so on until the circuit at T is for an instant interrupted and the armature enabled to return to its original position.

This plan is very useful in a country house where the entrance-gate is some distance off, as servants will often let a visitor ring without replying. With a continuous ringing, however, when the precaution has been taken to place the switch near the gate, it is necessary to go there to stop the noise.

This arrangement may also be adapted to a letter-box; every time the postman delivers letters he lifts the small

oblong lid which closes the box; this contact can be utilised to make the bell ring continuously—until the servant comes to collect the letters.

As the servants might purposely forget to re-establish the contact at T, it is easy to compel them to do this by arranging the contact in such a way that they will be obliged to break it by opening the gate or the lid of the letter-box, and to restore it by closing the door or the box.

It will be seen that the arrangements of electric bells may be varied indefinitely, and do not give rise to any serious difficulties if a little care and attention be taken in laying the wires.

The above general directions apply equally well to indicator-boards, which may be just as easily set up as simple bells.

CHAPTER III.

AUTOMATIC ALARMS.

TOGETHER with bells and indicator arrangements we may class the automatic alarms, which, as their name suggests, are intended to indicate automatically and to warn those whom it concerns of some phenomenon or accident.

Their number and arrangement may be varied indefinitely, but we will here only describe a few examples, for electricity presents a fruitful field to the hundreds of inventors who daily devise some fresh arrangement.

Thermometrical Indicators.—If we have a platinum rod sliding in the tube of a thermometer, the lower end of which rod may be fixed at any desired degree, it will be understood that if the temperature reaches this degree the mercury comes into contact with the rod, and that this metallic contact may be utilised to close a circuit to an alarm-bell, gas-tap, or any other suitable apparatus.

Fire-alarms. — Many of the so-called fire-alarms are made on the same principle as the thermometrical indicators, some, however, have this advantage, that they act at the same time as ordinary calls for domestic use, requiring no special installation.

In order to transform ordinary bell-pushes into fire-alarms, a small piece of fusible alloy is fixed to the lower spring so as to keep it pressed down and out of contact with the upper spring. Under these conditions it acts as an ordinary push, but as soon as the bit of fusible alloy melts, at a temperature of about 37° C., the lower spring rises and thus makes continuous contact with the upper spring, and the bell will

ring continuously, giving warning that there is a temperature of 37° C. in the neighbourhood of the push.

In Fig. 32, A is the upper spring, B the lower, which left to itself would at once make contact with A. The plug of fusible alloy is at C, and is held down on the spring by a screw through B. In Fig. 33 the arrangement is nearly the same. The lower spring is at B, the bit of fusible metal at C, and the upper S-shaped spring A bends to the pull of the bell-rope by means of a finger working in the hollow of the spring.

FIG. 32.

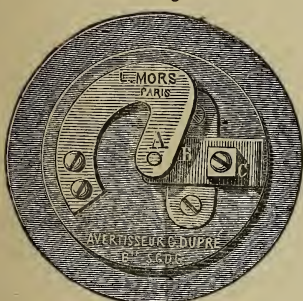
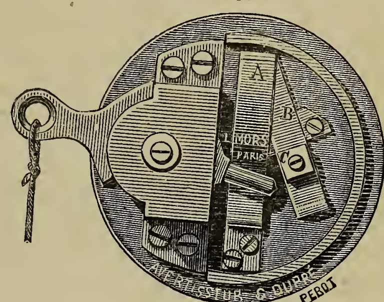


FIG. 33.



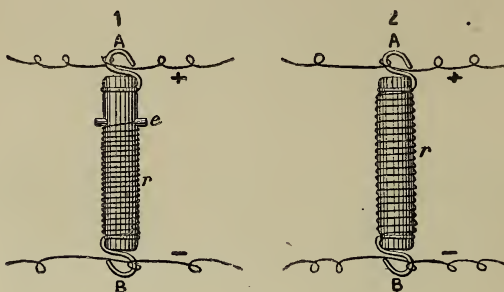
When the cord is pulled, the finger presses on the convex part of the spring, brings it down to the lower spring, and the contact being produced, the bell rings. On the other hand, in case of fire, the fusible metal disappears, the spring B makes permanent contact with A, and gives warning of the increasing temperature.

Forgeot's Fire-alarms.—These are also based on the rise of temperature caused by fire at a given point. The cylindrical rod of porcelain, ivory, or any other insulating material, shown in Figs. 34 and 35, about $\frac{3}{4}$ in. long by $\frac{1}{8}$ in. in diameter, has metallic hooks on top and bottom, A and B, to which the wires from the battery are attached. If the two hooks A and B are put into metallic communication, the circuit is closed and the bell rings.

To effect this automatically in case of fire, a metallic spring A is wound round the insulating rod, held at one end by the hook B, and at the other by a small pin *e*, of fusible

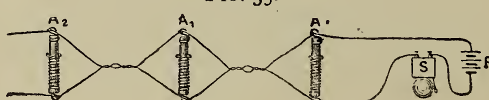
metal, inserted in a hole drilled through the rod, $\frac{1}{8}$ inch from the hook A. When the spring is held in this position the circuit is open, but as soon as the melting-point of the metal (55°) is reached, the pin melts, the spring extends and touches A, closing the circuit and ringing the bell.

FIG. 34.



The arrangement of apparatus to act as fire-alarms will now be easily understood. When a series of these very small instruments is fixed in any room, all joined to the battery and bell by common wires, which, being covered with silk, may be laid up

FIG. 35.



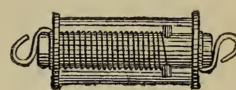
together to save space; it is very certain that as soon as any increase of temperature caused by the beginning of a fire is felt on any part of the wire the bell immediately gives warning of the danger.

The melting-point of the pin is 55° C., but this may be varied by modifying the composition of the fusible metal. A high temperature may destroy the elasticity of the spring, but electric contact would be established long before then.

An important point is to assure the actual contact between the extreme ends of the spring and the receiving hooks of the wire. These hooks and the spring itself are therefore gilt or nickel plated, and thus prevented from oxidising. But the contact may also be disturbed by dust or cobwebs, which will

not fail to make their appearance between the extremity of the spring fastened by the pin and the adjoining hook, unless frequently and constantly cleaned. In order to avoid this inconvenience each apparatus may be covered with very fine goldbeater's skin, secured in such a way as not to interfere with the motion of the spring, as shown in Fig. 36.

FIG. 36.



This apparatus, by merely changing the substance of which the pin is made (by using soluble instead of fusible material), gives a warning of leaks in cellars, holds of vessels, &c.

All the foregoing apparatus are rather temperature alarms than fire-alarms. If the regulation is not very exact, there is the risk that in winter they will not act, or act too late, and in summer give false alarms. An anonymous contributor sent to 'L'Electricien,' in January 1882, the description of an alarm, the principle of which we let him explain :—

"The most striking fact about a fire is the rapidity with which it spreads ; every alarm should therefore be based upon the rapidity of this increase of temperature during a fire, and not on the increase of the temperature *per se.*

"Acting on this principle, I constructed the following small apparatus :—

"This very simple and cheap apparatus is composed of two distinct thermoscopic couples. They are two U-shaped metallic strips, each consisting of a copper strip and a zinc strip soldered together. Zinc and platinum are the most sensitive plates, but platinum is dearer than copper, and it is difficult to find a solder of which the coefficient of expansion is the mean between δ Zn and δ Pt.

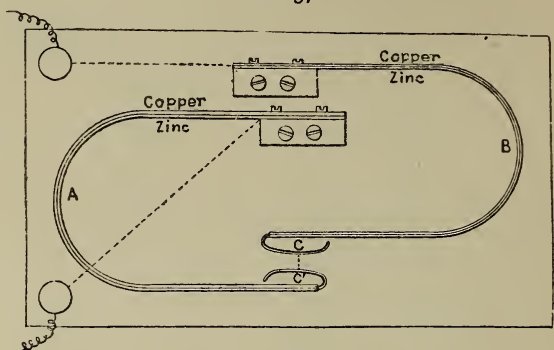
$$\text{Coefficient of expansion}\begin{cases}\text{Zinc} \ldots \quad \ldots & 0\cdot000029\\ \text{Brass} \quad\quad \ldots & 0\cdot000018\\ \text{Platinum} \ldots & 0\cdot000008\end{cases}$$

"One set of strips is thick, and the other exceedingly thin ; in the apparatus used by me for my experiments, one of the combined strips had a thickness of a fifth of a millimetre, and

the other a millimetre and a half; it is also deeper. They are, however, the same in length, the two zincs being on the inside.

"As soon as the temperature rises, the plates get heated and expand; by expanding unequally the two arms of the U tend

FIG. 37.



to separate; but as one is fixed, the whole effort is extended to the second arm, which opens out from the fixed point. But the plate B, the bulk of which is smaller, absorbs the heat more readily, so that if the increase is sudden and considerable, as it always is at the beginning of a fire, it expands rapidly and makes contact with A, which, being of greater mass, takes longer to heat and expand. If, on the other hand, the air becomes heated from ordinary causes, the rise in temperature always being more gradual, the plate A has time to expand, and the two contact points C C do not touch. These contacts are made of bent silver or platinum strips, so that the contact may take place in all positions of the plates. The advantages of this instrument are its simplicity, sensitiveness, low price, and automatic action for preventing false alarms."

Another indicator recently proposed is based on the same principle, but the two plates of unequal calorific capacity are replaced by two glass vials filled with air, of which the one is uncovered and the other covered with a material which is a bad conductor of heat, as, for instance, white cloth or felt. These two vials are joined by a horizontal glass tube con-

taining mercury. If the rise in temperature is gradual, the air expands in both vials equally, and the mercury remains stationary; if the rise of temperature be sudden, the air in the uncovered vial becomes heated sooner and drives out the mercury, which may then be used to close a bell circuit.

Breguet's Desk and Safe Alarms.—The idea of utilising the electric current to automatically give warning of the improper opening of a room-door or safe is certainly not new.

But if the systems are numerous very few are of much use, and it is to be supposed that thieves, whether born to thieve or having taken it up as a profession, know most of these contrivances and care very little for them. A wire properly cut reduces the obnoxious bell to silence.

But by the Breguet alarm this last resource is denied to the safe-pickers, the cut wire at once betrays their presence by giving the alarm on the bell, and if the wire is not cut the first movement of the door produces exactly the same effect. Thanks to this new combination, the safe becomes an object of forced respect, an idol which cannot be touched without warning its guardian.

This is arrived at by making use of a continuous current, and by utilising the opening of this circuit. An ordinary bell, a continuous-current battery, an ordinary Leclanché battery, and internal contacts which break as soon as the safe is opened, are all that is required. The continuous-currrent battery may be placed in the safe or any other suitable place, and forms the electric source of a circuit completed by the coils of the electro-magnet of the ordinary bell, the wires which lead to the safe, and the contact or contacts the breaking of which is to give the alarm.

The bell is also in circuit with the Leclanché battery in the ordinary way, but with no break in the circuit. The continuous current which circulates in the magnet of the bell, maintains the armature and the hammer close against this magnet, and in consequence keeps the circuit of the Leclanché battery open while the spring of the trembler and its screw are not in contact. But if from any cause whatever the

other circuit becomes broken, the armature flies back, makes contact with the trembler, and the bell rings loudly until the continuous circuit is re-established.

There is nothing to prevent a multiplication of the bells by placing them at several points. It is only necessary to break the continuous circuit at any point to make all the bells on this circuit ring at once.

This use of the continuous circuit also enables warning to be given at any moment if the system is not in proper working order, for if by negligence the continuous battery is allowed to run down the tingling of the bell at once gives the alarm.

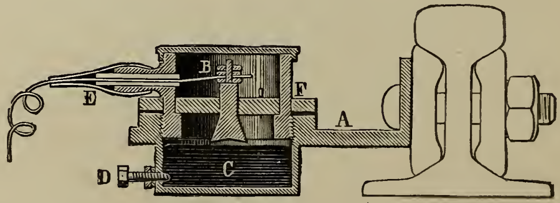
This continuous battery acts for a long time without having anything done to it, as the current required is insignificant, it being in fact only necessary to keep an armature in contact with its magnet, and a very small current will do this.

Thanks to this system, honest folk are protected against thieves, and we do not believe that the latter have a sufficiently profound knowledge of electricity to get round this combination.

In New York, however, safes with electric bells are out of date. We read in the 'Chronometrical Review,' that a German has invented a safe which not only rings a bell as soon as touched, but throws out a powerful beam of electric light, by means of which a photographic apparatus instantaneously takes the features of the thieves. (See the American papers !)

Fig. 38 shows a device for making contact when shaken, which was designed by Morse for railway purposes. This

Fig. 38.



small apparatus may be fixed against the door to be protected, as the slightest shake disturbs the mercury in C, which thus makes contact with B, closing the circuit of a battery and bell.

The screw D is to regulate the level of the mercury and render the apparatus more or less sensitive.

Abdank-Abakanowicz's Magneto-electric Call.— In many cases it is an advantage to dispense with batteries for ringing the bells, and to replace them by a magneto-electric system, in which the work necessary to give the signal is performed by the muscular energy of the operator. For example, in a telephone system where only magneto transmitters are used, the installation is much simplified by the use of magneto apparatus to work the call-bell.

In long distance telephoning it requires a number of cells to work the calls, which number increases in proportion to the distance, while a magneto call of a uniform price acts at any distance ; it is therefore economical to use it above certain distances, even with a microphone transmitter, because the number of elements necessary for the latter is almost constant.

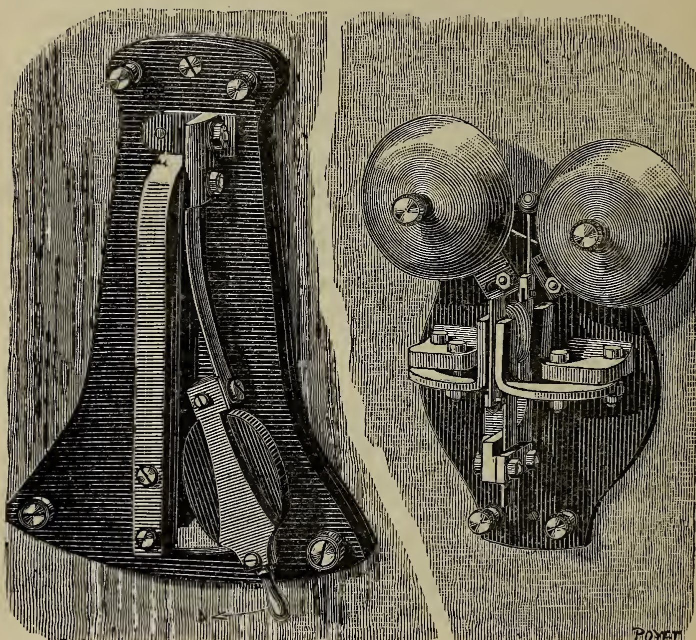
Fig. 39 represents the transmitter and the receiving-bell. The transmitter is formed of a U-shaped magnet between the poles of which works a coil with an iron core, and fixed at the end of a spring the other end of which is strongly fixed. The coil is moved from its position of equilibrium between the poles of the U-shaped magnet by pushing a button fixed to the lower part of the coil and then letting go. Under the action of the spring the coil oscillates rapidly, like a pendulum, between the poles of the magnet, and the wire of which it is composed is traversed by a series of alternately undulatory currents; these currents last some seconds, until the coil returns to its original position.

These undulatory currents thus produced arrive at the receiver, made of a second coil rolled on a sheet of thin iron plate in the form of a double T, and moving in a magnetic field constituted by two permanent magnets. This double T carrying the coil is fixed on a spring which enables its vibrations to be regulated, and renders them synchronous with those of the transmitter, which increases the sensitiveness of the apparatus. The other end is furnished with a small brass ball which strikes the two clock-bells alternately

when the coil is traversed by the undulatory currents coming from the transmitter.

The call thus constituted is very simple to manage, it acts in all positions and requires no keeping up. All that is

FIG. 39.



necessary is to fix the transmitter securely on a table or against a wall, and to couple it up to the receiver. To work it, the handle is pushed from its position until it nearly touches the stop on the other side, and is then let go. The undulatory currents produced by this system have the great advantage of not causing any induction noises on the neighbouring lines, owing to their nature and their periods of vibration, which exceed $\frac{1}{16}$ of a second, the lowest limit of perceptible sounds. This is a valuable quality which recommends its use for telephone purposes.

CHAPTER IV.

DOMESTIC TELEPHONES.

ALTHOUGH a recent invention, the telephone has made greater strides than perhaps any other discovery, and there is no knowing what future may not be in store for it. A regular network of telephone wires already covers every large city, and recent discoveries, which appear to promise that telephones and telegraphs may be simultaneously worked by one and the same wire, will make its use even more universal.

We propose to study the telephone in a somewhat more modest sphere by considering it as a useful and valuable adjunct to the other domestic electric apparatus which we have already examined.

We will, as usual, proceed from the simple to the complicated, and we first of all suppose that communication between two points in a house, office or factory, is to be made.

The first question is the choice of a system. We would advise the use of magneto telephones of the Graham Bell type if the distance is not very great, say, for instance, 100 yards or so. Simplicity, economy, and easy installation are combined here. Battery telephones certainly give better results, but they are dearer and require greater care and supervision.

The sounds produced by magneto telephones are small, it is therefore necessary to call attention by means of a bell.

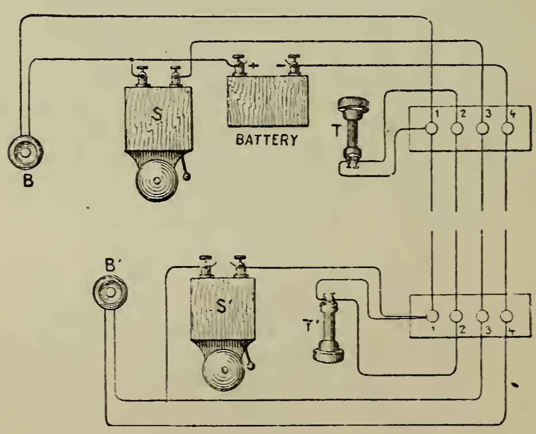
One of the most simple installations of a bell and a telephone possible, is to use an ordinary bell-push with one insulated wire and an earth return, the same circuit being used for the Bell telephone. In such cases the magneto call is very useful.

In most cases it is necessary that each station shall be

able to call the other ; a complete telephonic communication between two stations includes, therefore, at each station a telephone transmitter, which can act as receiver, or better, a pair of telephones, a call-button, a call-bell, and a battery. All these may be arranged in different ways, each presenting its special advantages and disadvantages ; the choice to be made between the different arrangements depends upon the special requirements of the proposed installations.

If the telephone is to be available to anybody, which is generally the case, it is absolutely necessary to do without every commutator or switch which may be forgotten to be replaced, and to do this a sufficient number of wires must be used, four at the most, or three, taking the gas- and water-pipes as return wires ; the call-button and telephone are sufficient to establish complete communication without the possibility of error. See Fig. 40.

FIG. 40.



On examining the diagram it is easy to follow the intercommunications of the various apparatus with each other—presses, bells, telephones, battery, and wires.

To avoid error it is advisable to attach first of all the four wires to four numbered terminals on a board fixed at each station, and then to join up the two sets of terminals. The

terminal and wire No. 4 may be replaced by water- or gas-pipes. The diagram of Fig. 40 shows all the apparatus close together, to enable the connections to be easily traced out. In practice, however, they are placed wherever possible, by adapting the buttons, bells, and telephones to suit the circumstances.

To make a nice appearance all the apparatus should be fixed symmetrically on an oak or mahogany board.

In other countries pairs of complete telephone stations may be bought all ready, with telephone, bell, battery, &c., and it is only necessary to screw the board up to the wall, lay the wires, and couple up to the marked terminals ; but in England, owing to the monopoly of the United Telephone Company, no one may make or use a telephone without a licence from them.

Telephone conductors placed inside a house may be of the same nature and size as ordinary bell-wires, but it is convenient to distinguish them by choosing different colours. Or the wires, two, three, or four in number, may be run in lead or compo pipes, fastened by hooks and staples, exactly the same as gas-pipes.

When the telephone stations to be joined are some distance apart, without an intermediate building, recourse must be had to an aërial line on telegraph posts, 18 or 20 feet high, of pine, fir or larch, impregnated with sulphate of copper or creosote to make them last.

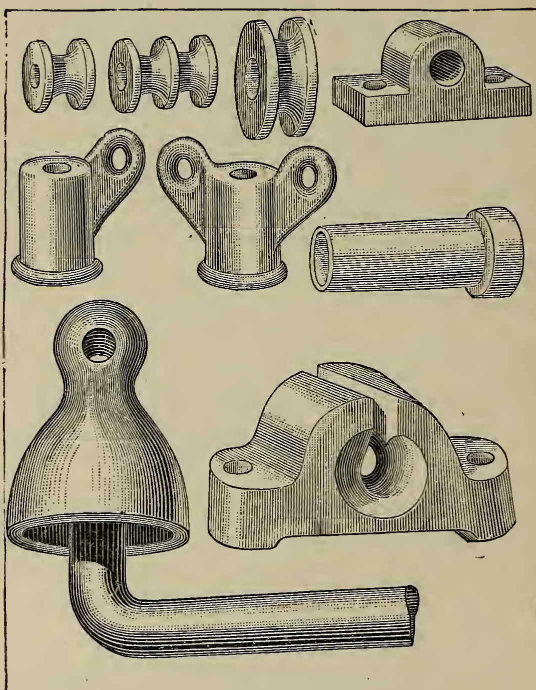
The wires should be galvanised iron or steel, from two to six millimetres diameter, according to the distance, or of silicium-bronze, eight-tenths to one millimetre in diameter. The silicium bronze wires allow of longer spans owing to their smaller weight ; the longest span of iron wire is from 80 to 100 yards, while 250 yards may be spanned with silicium bronze wires. Bare conductors must be fixed to the posts, or the buildings to which they are attached, by means of porcelain insulators, of which Fig. 41 shows some shapes, but many other patterns are used in this country.

Magneto telephones may be suitable for short distances and quiet localities, where the conversation is not troubled by

outside noises, but in manufactories, workshops, &c., microphone transmitters with batteries must be used.

For telephone purposes the Leclanché is the battery most used. It must not be forgotten, however, that they polarise

Fig. 41.



when kept continuously on closed circuits, therefore it is necessary to break the connection as soon as the conversation is finished. The Lalande and Chaperon battery, as well as accumulators, have been used with good results.

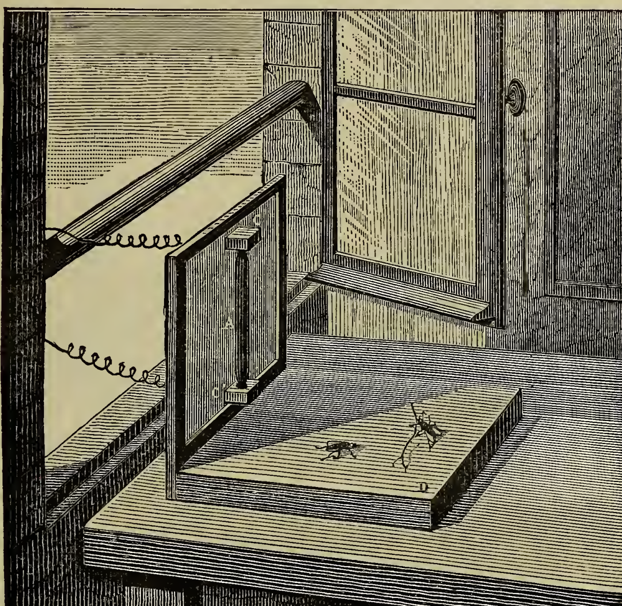
The transmitters vary indefinitely in form and arrangement.

We cannot here describe all the known variations capable of giving good results, many of which cost a good deal more than they are worth. Any one may make a very serviceable microphone with a few carbon pencils, like those used for arc lamps. Such is the microphone of Professor Hughes, who

invented this instrument, and gave it to the world without any patent. See Fig. 42.

It consists of a small pointed carbon pencil A, held tightly in a vertical position, between two blocks of carbon C C, fixed

FIG. 42.



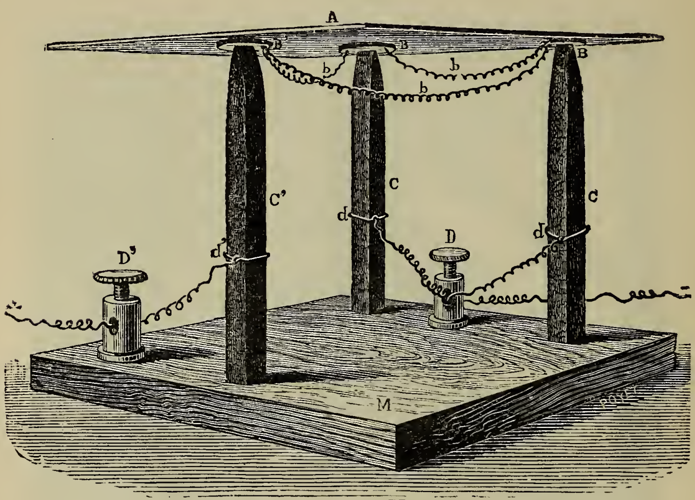
against a thin sounding-board on a solid base D. These blocks C C are joined to the battery and to the line wire which leads to the telephone. This instrument, even in a rough model, is of an amazing and marvellous delicacy. It has wonderful sensitiveness, almost too much, as it has to be diminished to destroy the crashing sounds produced by too intense noises.

This is done by several means ; sometimes the board which supports the carbon blocks is inclined until it is perfectly horizontal or slightly inclined like a desk ; sometimes a small piece of paper folded into the shape of a V is placed between the board and the carbon pencil, the elasticity of the paper is

sufficient to diminish the too great mobility of the carbon, and to eliminate almost entirely the crashing sounds.

Fig. 43 shows a very simple arrangement of the microphone, which will give good results, and is of so easy a con-

FIG. 43.



struction that only a few minutes are required to make one if the materials are to hand. The sounding-board A is made simply out of a visiting-card cut square, and of medium thickness. On this card three small light plates B B B′ of carbon, as used for electric lighting, are fastened by means of sealing-wax. These three plates occupy the three angles of an equilateral triangle ; they are put into communication by means of copper wires *b b b.*

For this purpose a small hole is made in each, when the end of a copper wire is fixed to it, and the three small copper wires are joined together.

The rest of the apparatus consists of a board M, holding the three carbon rods C C C′ corresponding exactly to the three plates B B B′. Two columns C C communicate by the copper wires *d d* with a terminal D. The third column C′ is connected to a second terminal D′. The upper ends of the

carbon sticks should be bevelled, as pointed ends do not give such good results, and the other ends of the carbons must be fixed to the base board with wax.

This little instrument may be made very sensitive to the voice and all other sounds, provided a suitable weight, neither too heavy nor too light, be placed on the card A. A person speaking in his usual voice at the end of the room in which the microphone is, may be heard distinctly, and the voice and tone of the speaker easily recognised. Piano sounds are particularly well heard. It is necessary to place the apparatus on a table two or three yards away in order that the mechanical vibrations may not affect it.

A Leclanché battery of two or three cells is required with this microphone.

In the Locht-Labye transmitter, to which the inventor has given the somewhat pretentious name of Pantelephone, the contact of variable resistance is formed between a fixed piece of platinum and a small carbon lozenge attached to a plate of cork suspended by two springs on the upper part; the cork plate offering little inertia, and having a great surface, follows the voice well.

A very simple transmitter, easy of construction, is that of d'Argy, and it may be made of materials ready to hand.

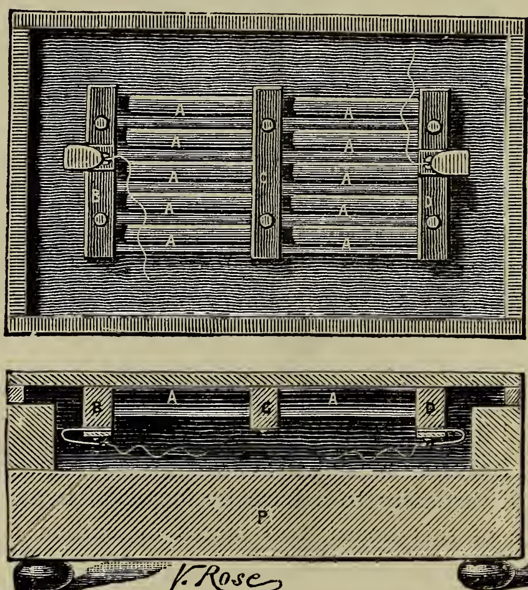
Take a board of walnut, deal, ebony, or a Japanese hand-screen, fix it vertically to a base by means of two corks. In the middle of this board, two pieces of carbon are fixed, between which a pinch of coke is placed, held by means of a piece of indiarubber tube or the nipple of a feeding-bottle. The vibrations of the board react on the variable contact resistance formed by the powdered coke.

Practically, good results are obtained by multiplying the contacts and by arranging them either in tension or quantity. In the Ader transmitter there are ten carbons, which give twenty contacts, four in tension, and five parallels. Crossley's transmitter holds four carbons, eight contacts, four in tension and two in quantity; the Gower Bell, six carbons, twelve contacts, three in quantity, four in tension, &c. In all these instruments it is necessary, in order to obtain good results, to

proportion the number of elements to the number of contacts and to their arrangement: if the contacts are in series the cells should be in series ; if they are in quantity, the cells should be arranged in quantity. The rule to be followed is, that the internal resistance of the battery should be as near as possible equal to the mean resistance of the transmitter.

Ader's Transmitter.—This transmitter, mostly used in France, Fig. 44, is made of ten small carbons A A, arranged

FIG. 44.

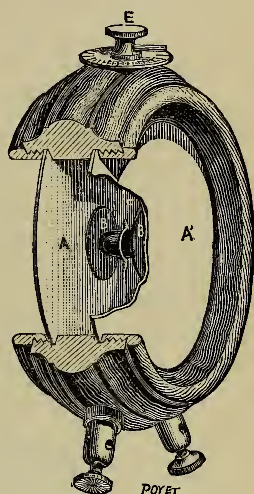


two in series and five parallel, supported at their ends by three cross-pieces of carbon B C D fixed on a light pine-board, which receives the vibrations and at the same time serves as a cover for the apparatus. For ordinary use it is fixed directly to a board ; for theatrical purposes it is fixed to a leaden base, supported by four indiarubber feet, which shield it from the shaking of the stage.

Dunand's Microphone.—This microphone transmitter in which the contacts are protected from air and dust, seems to possess some advantages. It is made of two metallic plates

A A, Fig. 45, fixed on a wooden ring, making an air-tight case protecting the microphonic system against air and dust, which in ordinary microphones sometimes interferes with the contacts. Each of these plates has a small carbon lozenge B B fixed in the centre. Between these two carbon lozenges is a small egg-shaped piece of carbon, of a somewhat greater length than the distance between the inside faces of the carbon lozenges. This is held in the middle by a brass wire F, stretched diametrically, one end of which is fixed and the other end joined to a button E. By twisting the wire more or less the egg-shaped carbon is pressed with varying force against the two lozenges, and the microphone becomes proportionately sensitive. An index fixed to the button E makes it easy to regulate the twist of the wire in order to proportion the sensitiveness of the instrument to the nature of the sounds to be transmitted. The variations of resistance are produced by speaking before one of the plates; two persons, one speaking into A and the other into A′, may even transmit a duet, which the receiving apparatus reproduces clearly and distinctly.

Fig. 45.



A transmitter may act upon a telephone receiver in two distinct ways :—

1. Directly, without the intermediary of an induction coil.
2. Indirectly, by means of an induction coil.

The first system can only be used with very short distances, as for example from one room to the next, and using a telephone wound with comparatively thick wire. It will, in fact, be understood that, as the distance increases, the total resistance of the circuit, constituted by the battery, the transmitter, the receiver, and the wire, increases also, while the variations of the resistance of the transmitter always retain their absolute value. The effect of these variations will therefore be less

as the distance increases, and finally becomes insufficient to make the sounds perceptible.

This, however, is not the case if induction currents are made use of.

The transmitter works on a circuit of fixed resistance, consisting of its own resistance, the resistance of the battery, and that of the primary circuit of the induction coil, while the receiver and the line wire are in circuit with the secondary coil. The length of the line wire, in this case, only indirectly affects the instruments, and by proportioning the wire on the induction coil and telephone to the length of the line wire, the requisite regulation and sensitiveness may be obtained, always remembering that the longer the line, the finer and longer must be the wire of the coils. Most of the telephone stations erected at present are furnished with induction coils, and act easily up to ten or twelve miles and over.

Telephone Stations.—For domestic or private telephones the two stations are generally joined to each other permanently, as for example between an office and a workshop, a manufactory and the house of the manager, a country house and the lodge-keeper, &c., &c.

As battery telephones are intended above all to satisfy the requirements of a somewhat long line, it is impossible to use a great number of wires, two at the most are used, and often only one, the earth acting as return.

Under these circumstances a commutator is necessary, in order that when no message is being sent, and the instrument is not in use, the line wire is connected to the bell, that when a call is made the battery at the station making the call is connected to the line, and that when the call has been answered and conversation is being carried on the telephones are in connection through the line and battery.

In the early days of telephones all these various connections were made and broken by switches worked by hand, but at present automatic commutators are almost invariably used.

All existing stations are so arranged that the telephone when not in use is hung on a hook, which is in reality a lever switch controlled by a spring. When a conversation is ended

the speaker returns the telephone to the hook, and its weight pulls it down half an inch or so, thus breaking contact with the telephone and putting the bell in circuit.

Each station includes :—

1. A battery of some Leclanché cells, which serve both for the call-bell and the transmitter.

2. A call-bell.

3. A call-button.

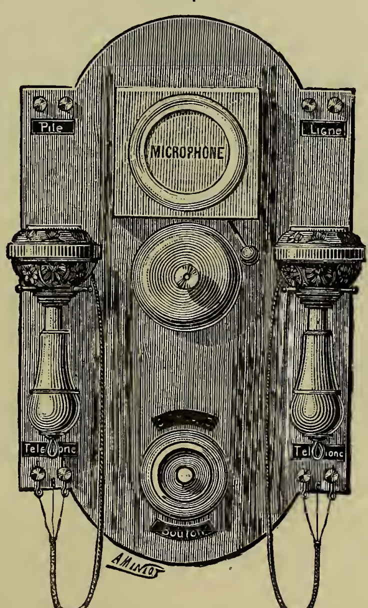
4. A transmitter for speaking into.

5 An induction coil, generally placed out of sight in the case of the apparatus.

6. One or two magnetic telephone receivers.

Dunand's Telephone.—Fig. 46. Everything is systematically arranged on a board from which go four wires, two to battery and two to line ; the Dunand microphone is fixed on

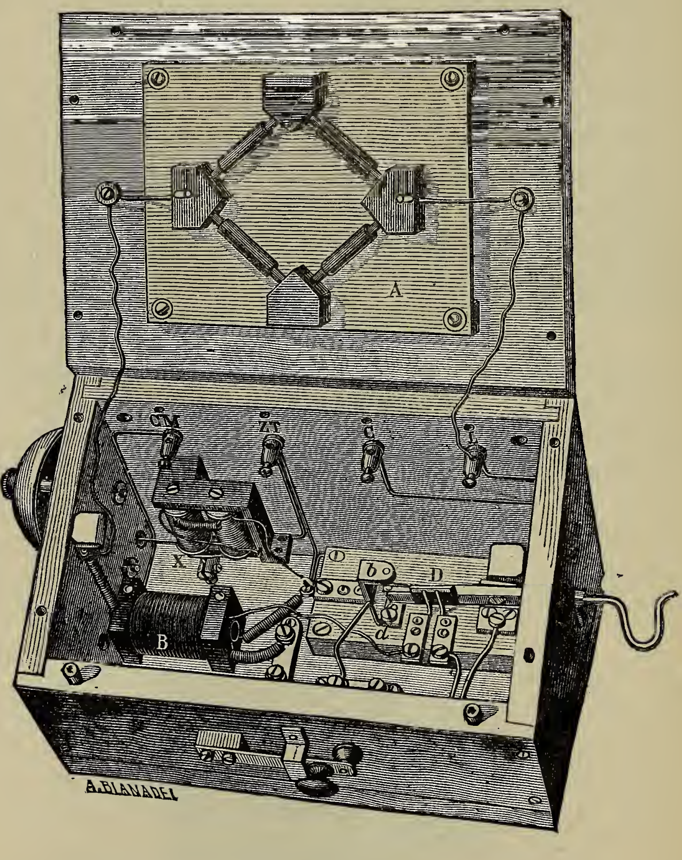
FIG. 46.



the bell-case itself, the button is below, and the receivers are two Bell telephones, the right-hand one producing the automatic commutation.

Crossley's Telephone.—Fig. 47. Here the call-button is in front of the case which holds the entire system, the bell N on the left, the hook commutator C on the right, and the

Fig. 47.

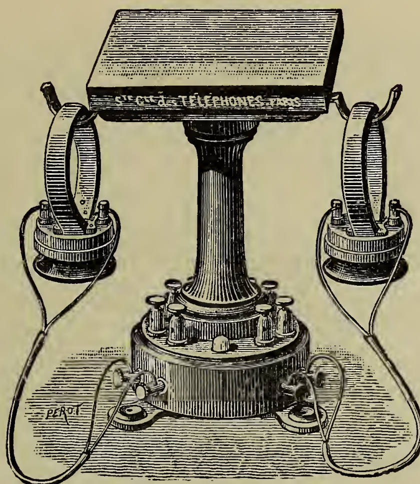


mouthpiece on the upper part. At A, Fig. 47, will be seen the carbon lozenges arranged in two parallels each with four contacts in series.

Ader's Portable Telephone.—In this pattern, shown in Fig. 48, the foot carries the call-button, the transmitter in the form of a desk, and the two Ader receivers. Flexible wires connect the instrument with the battery, the bell fixed

elsewhere in the room, and the line wire, thus enabling the transmitting and receiving apparatus to be moved about to a certain extent.

Fig. 48.

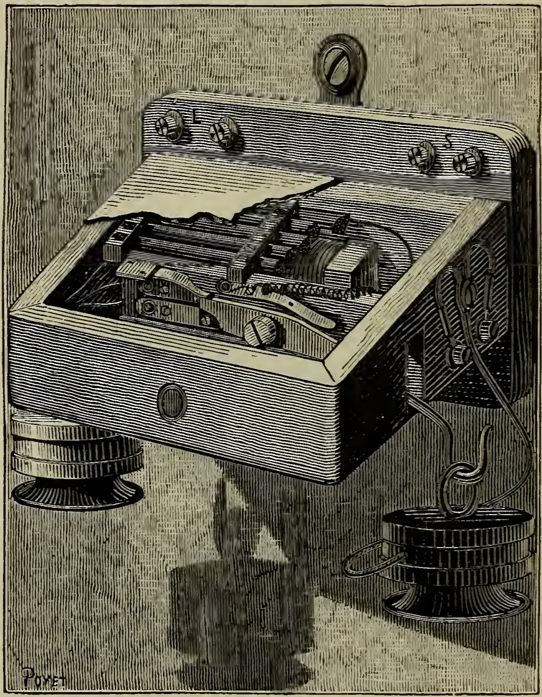


Bert and D'Arsonval's Telephone.—In this arrangement the carbon pencils of the transmitter are surrounded by a small sheet of tin ; a magnet acting on these sheets produces thus a magnetic regulator, enabling the transmitter to be used in any position. With this magnetic regulator a transmitter may be held in the hand while the other parts of the apparatus are in a small case, hung on a wall.

Simplified Telephones.—Under this name the General Telephone Company (French) constructs small telephones intended specially for private use, and of a price within an amateur's reach. Fig. 49 represents one of these telephones. The greater part of the vibrating board, forming the top of the desk, is shown broken away, in order that the internal arrangement may be seen. The transmitter is a microphone on Ader's system of ten carbons : the induction coil and the automatic commutator are arranged underneath, in the body of the desk; the call-button is in front, where the lock of an ordinary desk would be. All the connections are therefore

inside, and the erection of the telephone is very simple; it requires eight connections to be made, and these are clearly indicated: two go to the line wire L, two to the local bell S,

Fig. 49.



two to the local battery of the telephone, and two to the call-bell under the desk.

The handling and the action of the simplified telephone are identical with those of an ordinary telephone. When the right-hand receiver is hooked up, the telephone is out of action, ready for a call; when it is taken in the hand, the switch lever rises and closes the circuit on the telephone.

Figs. 50 and 51 show in section and elevation a telephone, the novelty of which consists in the magnet, made of a steel ring, having two screw threads and two internal soft iron pole-pieces, on which two flat coils are fixed, coupled in series

and joined to the line wire by means of a flexible cord. The round magnet has its two poles diametrically opposite, and the magnetic distribution is the same as in Duchemin's circular compass. On the lower thread a lid is screwed with a ring,

Fig. 50.

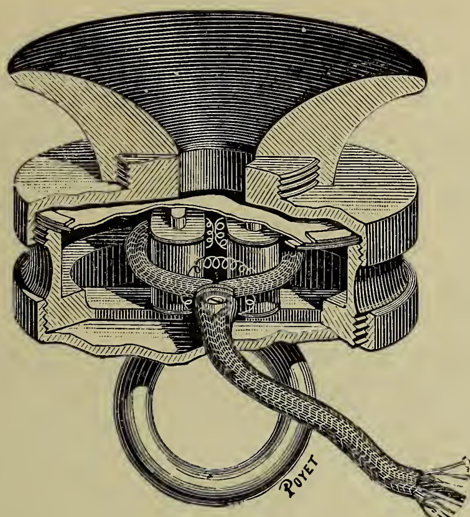
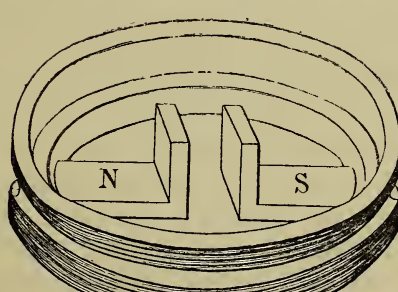


Fig. 51.

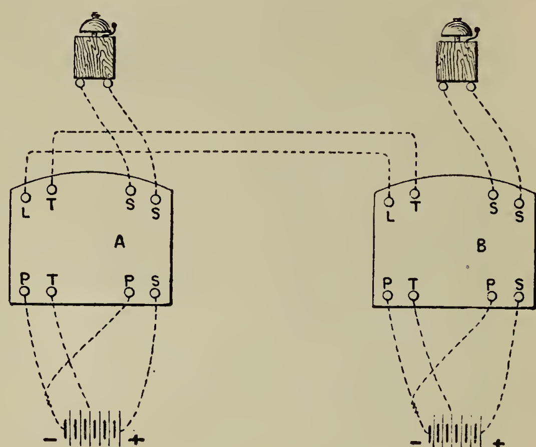


by which the telephone is hooked up when not in use; the upper thread takes the cover, mouthpiece, and the vibrating diaphragm. The distance of the plate from the poles is regulated by inserting brass washers of suitable thickness,

The telephone so constructed forms a compact whole, rigid, and not easily put out of order.

Erection of Telephone Stations.—Fig. 52 shows the coupling up and connections necessary for two complete

FIG. 52.

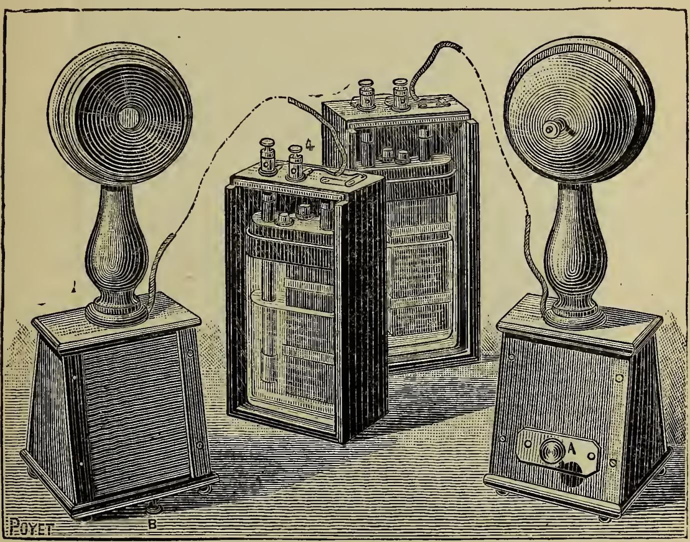


telephone stations, batteries, transmitters, receivers, and bells. The number of elements necessary to work the bells varies with the distance, while that of the elements required for the microphone system varies very little with this distance, generally three Leclanché cells in series.

Mildé's Telephone Station.—Without contradiction, simplicity, elegance, and cheapness, for small telephone stations, are combined in the apparatus shown in Fig. 53. The whole apparatus is movable, and comprises the transmitter—a D'Argy microphone, a round Bell receiver, call-bell, button, and automatic commutator. The battery — one Leclanché cell for each station—is fixed, and may be hung against a wall, or hidden in a corner of the room. In the most recent pattern it is hidden in an elegant bracket, used to stand the apparatus on. In the ordinary position, or when at rest, the apparatus stands on a table or bracket. A button B fixed underneath, Fig. 53, is thus lifted, and puts the bell in circuit. Pressing the button A, the right-hand station calls

up the left-hand station, which in its turn calls up the right-hand station. The two interlocutors have then to take the apparatus by the handle, and by putting it to the ear automatically put the telephones in circuit.

FIG. 53.



The instrument is so made that when the receiver is put to the ear, the rectangular board of the transmitter comes near the mouth, on the side, and a little obliquely. When the conversation is finished, and the apparatus replaced on the table, communication with the bell is again established.

The whole thing is compact and light; the two stations and their batteries, with 60 yards of wire, are enclosed in a neat box, and make a charming present to give to young amateur students of electricity.

Telephone Elbow-rests.—In many of the combinations of private or central telephone stations, the caller has to hold the receiver to his ear, waiting for the reply. The annoyance of waiting, and the fatigue of the position, make the time often seem longer than it really is.

Lhoste's Elbow-rest, the use of which will be readily understood by looking at Fig. 54, reduces the fatigue, and

FIG. 54.

patience may be more easily exercised. By means of a metal arc and a catch, the height can be easily regulated to that of the speaker.

CHAPTER V.

ELECTRIC CLOCKS.

THE uses to which electricity may be put, for the indication and measurement of time, are of various kinds.

Sometimes it may be used to transmit at regular intervals a signal or mechanical action to regulate and set the time of a clock or a series of clocks, each working independently in the ordinary way.

Sometimes it is itself the motor, which from a distributing centre works a number of dials situated at a distance.

Finally, it is sometimes the motor of the clock itself, where it replaces the spring or weights required to be wound up daily, weekly, or fortnightly.

In order to get rid of this necessity a system has been sought for capable of acting indefinitely while the battery lasts, and the patented variations and adaptations are almost without number.

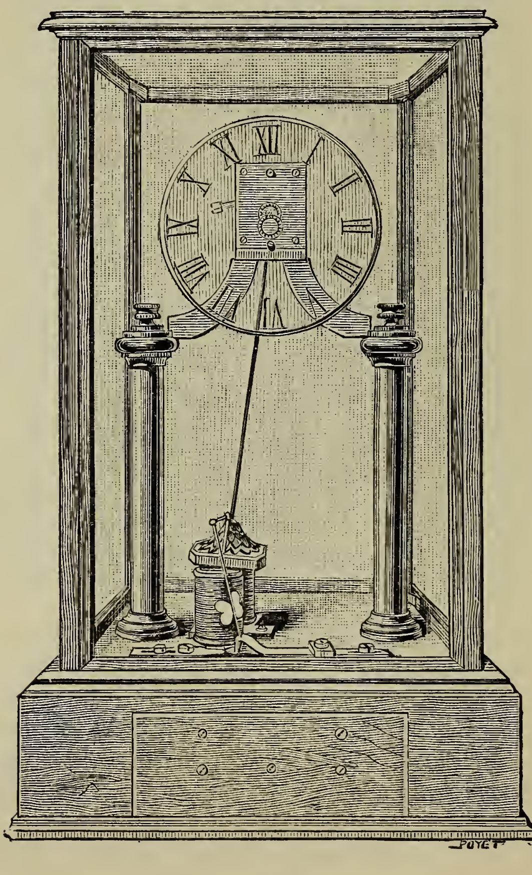
Electric Butterfly Clock.—A battery capable of supplying a given quantity of energy, dependent upon the volume of liquid, its composition, the thickness of the zinc, &c., would very soon be exhausted if it had to furnish a current to give an impetus to each tick of the pendulum. But experience shows that this impetus is only required now and then.

In the clock shown in Fig. 55, Lemoine only gives this impetus at the moment when it is necessary in consequence of the decrease of the amplitude of the oscillation of the pendulum ; a considerable saving of the battery is thus effected, which therefore lasts longer, while waste of electric energy is avoided.

This clock has an ordinary train of wheels worked by the

pendulum, which in this instance is the motor, having on its upper part a clutch or pawl acting on a ratchet on the axis of the first motion. Let us suppose the pendulum to be moved by hand. Owing to the resistance of the air and the work

Fig. 55.

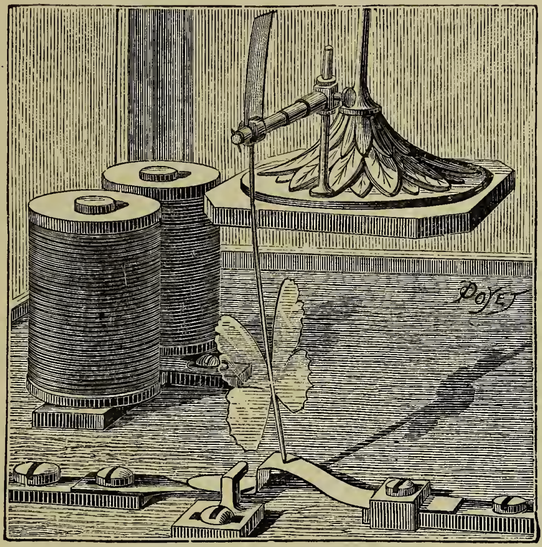


done by turning the clockwork, its amplitude of oscillation decreases gradually and will soon be stopped if the motion be not kept up. The pendulum, the lower part of which is a cylindrical iron disc, has a small rod, Fig. 56, which moves very freely round a horizontal axis, and to which is fixed a

thin piece of mica or paper cut in the shape of a butterfly, which gives the system its name.

During the motion of the pendulum, the resistance of the air makes the properly regulated rod take a more or less inclined position. When the speed and therefore the amplitude

Fig. 56.



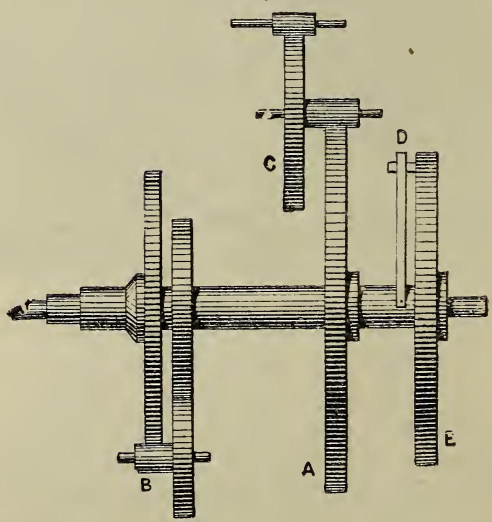
of the motion of the pendulum is sufficient, the extremity of the rod glides without depressing it over a very flexible contact spring on the base of the clock. When the amplitude decreases, the rod becomes more vertical, it then meets the contact, depresses it, and sends a current into the magnet placed on the left of Fig. 55. This latter attracts the pendulum and gives it an impetus, thereby recovering the amplitude of oscillation.

The pendulum then makes 6, 8, 10 or 12 oscillations without making contact again, and consequently without expenditure. By this ingenious arrangement the clock is kept going automatically at the required speed, by means of a fresh impetus given to the pendulum every time the speed of the oscillation has arrived at its lowest point.

It is very curious and amusing to watch the working of this arrangement. With it a separate battery may be used, or the battery may be placed in the stand.

Schweizer's Electric Winding-up Arrangement.—With the view of reducing the frequency of a closed circuit on the battery, and to use to the utmost the disposable work every time it is closed, an electric winding-up arrangement has been devised by Schweizer. The battery circuit is closed every time it is necessary to maintain at an equal tension a spiral spring which transmits the motion to the clockwork. The motive force is therefore entirely independent of the current and the electricity has only to wind up a spring at regular intervals. It consists, Fig. 57, of a wheel A, mounted

Fig. 57.

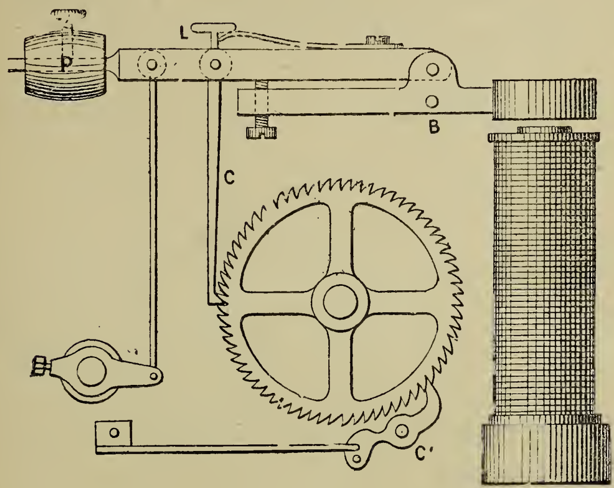


on the axis of the dial and moving the hour and minute hands B. A second wheel C, placed above the first, transmits the motion of the wheel A to the escapement. A spring D, fixed on one side of the shaft of the minute wheel, the other end being pressed against a pin in the ratchet wheel E, on the shafts of the minute wheel, conveys the motion.

Pressure on the end of the spring, in the direction of the

motion of the hand, puts the wheels in motion. This motion is transmitted by the pin on the ratchet wheel, driven in its turn by a weight P, Fig. 58, on the extremity of the lever L, by means of a pivoted pawl C. The fall of the weight P is very limited, and it is necessary to relift it whenever it gets near the end. The electricity does this automatically by means of a beam B, Fig. 58, on which is pivoted the lever L. On one end of this beam is a soft iron armature over an electro-magnet, and on the other a regulating screw. The

Fig. 58.



magnet is worked by a battery of two Leclanché cells. When the current passes, the weight P is lifted up without affecting the ratchet wheel, which is then held by the pawl C. This movement does not therefore affect the action of the apparatus, however suddenly the magnet pulls home its armature. When the current stops, the weight begins to fall again, turns the ratchet several teeth by means of the lever C, and gives to the spring its required tension.

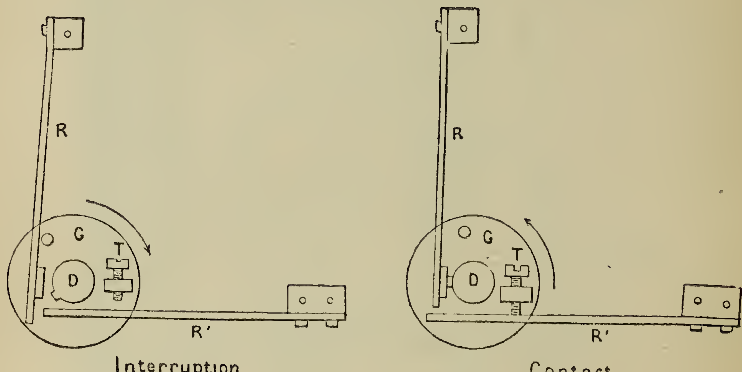
The circuit is closed only for a very short time, which insures a long duration of the battery, and the motion of the beam being independent of that of the lever, it returns to its original position without hindering its motion.

The lever and weight are very quickly lifted by the current, which once effected, it can do no more useful work, and therefore to save the battery the circuit should only be closed an instant every time the lifting of the weight is necessary, that is to say that the contact should in some way be momentary.

This is effected by means of the disc D, joined to the lever L, Fig. 58, by a connecting rod which moves it on its axis in one way or the other according to the motion of the lever L which governs it.

Fig. 59 represents the two positions of interruption and contact of the disc commutator governed by the rod.

FIG. 59.



The sketch on the left shows the circuit broken. As soon as the weight falls, the disc turns slowly as shown by the arrow until the moment when the screw T on this disc presses the spring R, the contact spring drops, touches the flat side of the disc, and closes the circuit. By the action of the magnet the lever rises, the disc returns in the reverse way, and the pir S pushes back the spring R and then takes up its original position again, thereby breaking the circuit.

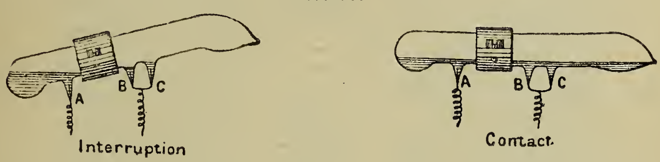
Leclanché has modified the dry contact by substituting a mercury contact.

The disc D, governed by the connecting rod of the lever

L, as in Schweizer's commutator, has a collar to take a small glass tube in which are several swellings.

The two ends of the tube form a reservoir, the slender parts A, B, C, Fig. 60, are traversed by platinum wires soldered in. The tube filled with hydrogen is also closed up with a blow-pipe after a small quantity of mercury is introduced. The wire A on the one side, and B and C on the other, close the circuit. The two wires at B and C, joined together, are a precaution in case during the displacement of the mercury one of them should fail.

FIG. 60.



After what we have said about the dry contact, the mercury commutator will be easily understood and it will be seen that in no case can the circuit be closed continuously.

Employment of bells for striking the hours.—If it be desired to transmit the time, and to repeat it on clock-bells or house-bells, the following very simple arrangement has been devised by Langé, watchmaker of Béziers.

We use a simple clock, no matter of what construction as long as it strikes. We take the negative wire of a bell-battery, and fix it to a metallic part of the works. The positive, properly insulated from the other parts of the clock, is placed a little above the rod of the hammer. When the clock itself strikes, the hammer rises, the rod touches the positive wire, and the contact is made.

At the same instant, all the bells in the circuit strike the same hour as the clock.

This experiment has been successfully tried, using a single agglomerated Leclanché cell. By enlarging this application the time may be given to all the rooms of a house.

It is easy to apply the system to church or public clocks.

Another adaptation is to cause a clock to strike at will, by simply pressing a button. This button forms the circuit of a Leclanché battery on a magnet which unlocks the striking gear.

If it is desired to know the time at night, one has only to press a button fixed at the head of the bed.

Alarm Clocks.

Nothing is simpler than to transform an ordinary clock into an electric alarm, and the following is an example :—

One of the wires is joined to any metallic part of the clock, while the other is joined to a small support made of a vertical rod over which a spiral copper wire can be slipped bent towards the middle to a right angle, in such a way as to form a horizontal arm on which another rod can turn, having a hook at the end ; this simple arrangement being completed, any necessary position can be given to it, so as to place it against the dial of the clock where desired, so that the large hand passes freely above the hook, while it bars the way of the small hand in such a way that when the latter comes to the spot where the hook is placed, it meets it, thus making contact and ringing the bell ; if this little apparatus be lightly made it can in no way disturb the regularity of the clock, especially if one takes care to get up to remove it.

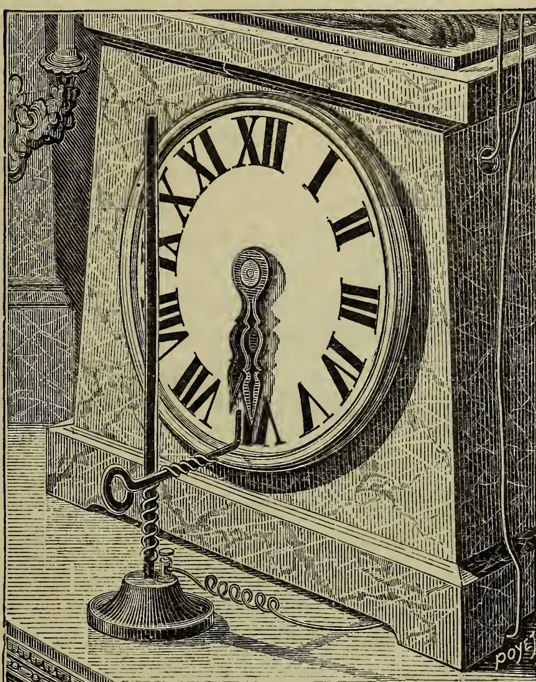
It is not, however, necessary to attach one of the wires to the works of the clock if we use the hour hand to bring together two ends of wire so arranged as to close the circuit. The support must then carry the two wires insulated and stripped only at the two ends which the hand will cause to touch.

Another way is to join one of the wires to the works and place the other, ending in a piece of platinum wire of $\frac{1}{10}$ mm. diameter, flat on the dial over which the glass of the clock is shut. The wire at this point is insulated by means of a bit of paper, which will not prevent the closing of the glass.

The arrangement of these alarm clocks may be varied indefinitely according to the ingenuity and skill of the amateur electrician.

We cannot conclude these remarks without reference to the three-contact clock of Dr. Ranque. Suppose we wish to

FIG. 61.



get up at 7 A.M. At 6.45 the first contact is made and sets light to a spirit-lamp placed under a kettle of water ; at 6.59 the alarum goes off, and a few seconds afterwards a third contact lights a lamp. The amateur thus finds himself aroused, the room lighted, and a kettle of warm water ready for his toilet.

CHAPTER VI.

ELECTRIC LIGHTERS.

AMONG the valuable services which may be rendered by electricity for domestic purposes, are gas, lamp, and fire lighters.

Electric lighters may vary much in shape and arrangement according to the use for which they are intended, the places where they are to be put, the combustible which they are to set alight, &c.

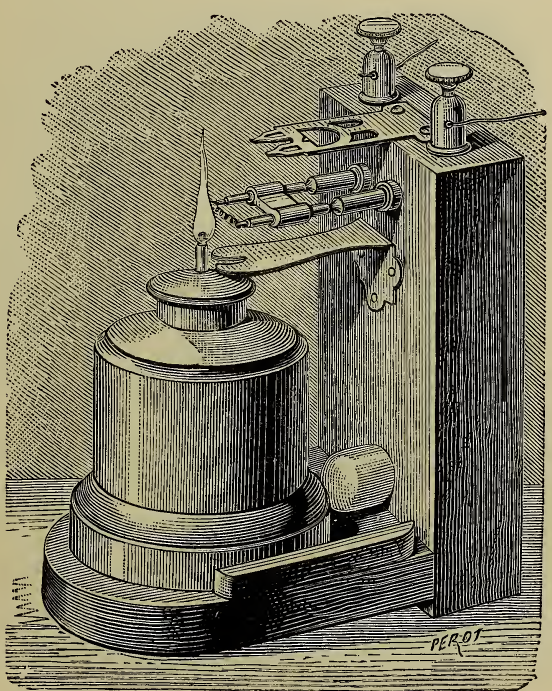
We will, however, here only describe the simplest and most practical of the numerous devices contrived.

To set fire to a given combustible substance an incandescent material must be brought into contact with it, at a temperature varying with the nature of this substance, moderately feeble for gas, greater for petroleum, and white heat for a stove or a candle. For this purpose platinum wire is generally used, rendered instantaneously incandescent by the passage of an electric current. The temperature of this wire depends entirely upon the current which traverses it. If this current be sufficiently strong, platinum, chosen on account of its inoxidability and its high point of fusion, will rapidly melt ; if the current be too weak, the temperature of the wire will be too low and the substance to be lighted may not take fire. Experience will enable one to avoid these two extremes and to so arrange the battery power that the wire will hardly ever melt, and that a light is always produced. A very fine wire will glow with a very weak current, but it will then be very fragile and subject to breakage from the slightest accident. It is therefore advisable to use wires tolerably strong (varying generally from $\frac{1}{10}$ to $\frac{2}{10}$ of a millimetre in diameter), but the current must then be a little stronger. The necessary current

is easily obtained by using cells of large surface having a low internal resistance, and as for a given E.M.F. the current diminishes as the internal resistance increases, it is advisable to reduce this internal resistance as much as possible.

The platinum wires are generally coiled into a spiral, the object of this arrangement being to concentrate the heat in one spot so as to increase the temperature at that point as much as possible. A weaker current may therefore be used than if the same wire be simply stretched out straight. In fact a wire traversed by a uniform current hardly glows when extended, while it gets up to white heat when coiled into a spiral, because in the second case the heat lost by radiation is much reduced.

Fig. 62.

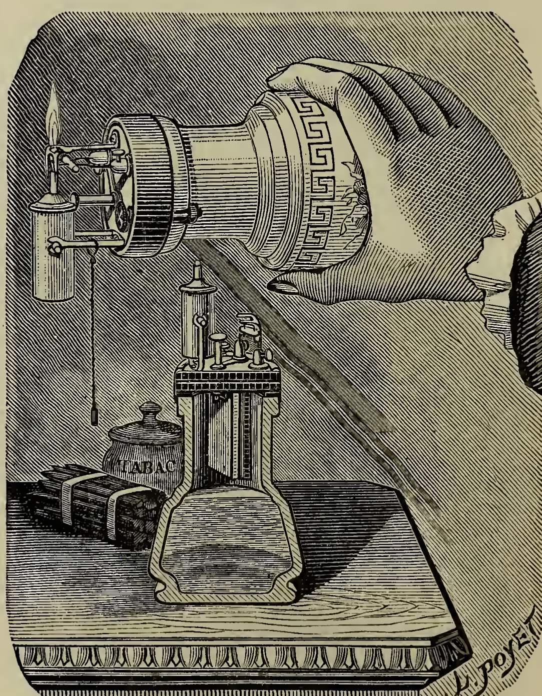


Loiseau's Lighter.—Fig. 62 represents a spirit or petroleum lamp for the use of smokers. By pressing the lamp against the wall the wick is brought close to the spiral

and the lamp presses a button which closes the circuit from the battery. On releasing the lamp it is pushed a little forward by the spring of the button and by this simple arrangement the spiral is never in contact with the flame and therefore lasts a long time. A very fine flattened wire is used and the current from a single cell is sufficient to light the lamp. The apparatus is so arranged that any one can easily replace the spiral in an instant in case it is accidently spoiled.

With all lighters for spirit or petroleum lamps it is important that the spiral never touches the wick: it should be brought a little over it and to one side in the mixture of air and inflammable vapour.

Fig. 63.



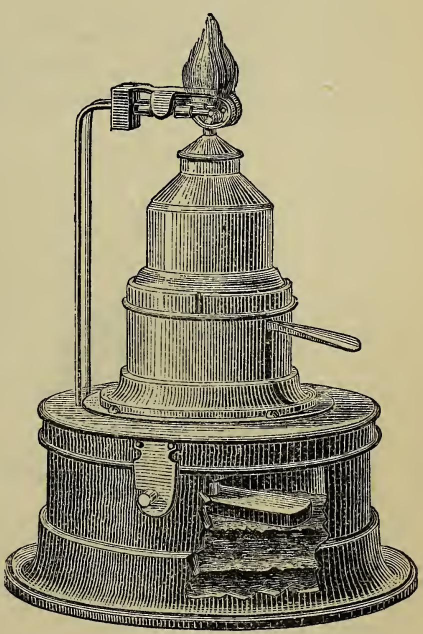
The Luciphore.—This is also an apparatus intended for smokers. It is composed essentially of a bichromate of potash battery in a bottle and hermetically sealed. The two

poles of the battery are joined to a very small platinum spiral fixed above the lighter. When the battery is in its ordinary position the liquid does not touch the zinc and carbon. By taking it up as shown in the figure the liquid covers the electrodes and the spiral glows, but the same motion also brings a small spirit or petroleum lamp towards the incandescent spiral, which lights at once.

From 500 to 600 lights may be had without exhausting the liquid ; the apparatus is again charged by renewing this liquid with the chromic salt prepared by dissolving 4 oz. of bichromate of potash in a quart of boiling water and adding 6 oz. of sulphuric acid to the solution when cool.

Unfortunately it is difficult to make a hermetically tight joint, and owing to the damage caused by the leakage of the acid solution this form of lighter is not much used.

FIG. 64.



Desruelles's Lighter.—To avoid the defects of the Luciphore the small lighter shown in Fig. 64 has been devised. This application may be used with all batteries, and consists in the introduction into the batteries, in place of liquids, of a sort of asbestos sponge, soaked in acid or any suitable solution. This gives a species of dry battery which may be moved, displaced, or upset without any liquid spilling, which is of advantage for movable appliances, such as portable lighters, batteries for bells on board ship, railways, &c.

The lighter is composed of a small raised case of wood, in which the battery is inclosed : in this case a small spirit-lamp

is placed ; a platinum spiral near the wick produces the light.

The battery is a bichromate of potash element in which the liquid is replaced by an asbestos paste soaked in a bichromate solution identical with that of the bottle batteries.

The zinc is suspended from a small lever which when pressed brings it in contact with the paste ; the circuit is then closed, the zinc is attacked and the current produced flows through the spiral which glows and sets the spirit alight. When the spiral no longer becomes red the paste must be renewed, which is a very simple operation. When the lever is not pressed the zinc is of course held up and out of action. On the same principle may be constructed gas lighters, the battery being in the handle, which may be of any required length.

The fault of this apparatus is that the space oocupied by the inert substance leaves little room for the liquid, that is to say, the exciting agent. The paste must therefore be frequently renewed, which is practically a great inconvenience.

FIG. 65.

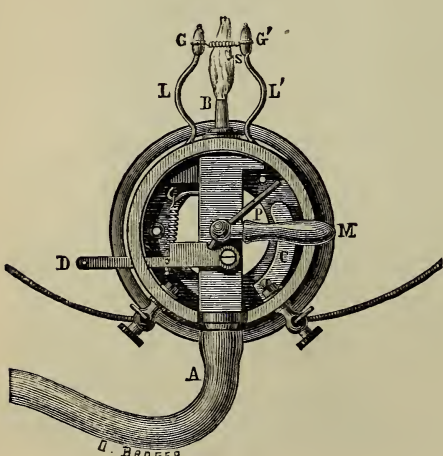
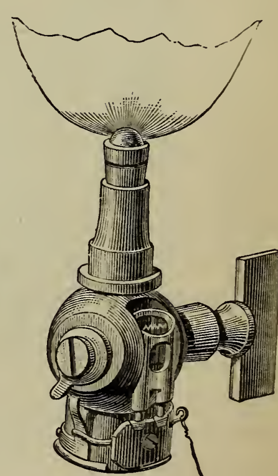


FIG. 66.



Gas Lighters.—Several arrangements for lighting gas by electricity have also been brought out, and we will describe

some of them. A very simple one is that shown in Fig. 65, for smokers, candles, sealing a letter, &c. It consists of a small gas-burner B on a round case about 3 inches in diameter, and joined to a gas-pipe by an indiarubber tube A. By moving the handle M the tap is opened, and an electric contact established of sufficient duration to make the spiral G G′ glow and light the gas. It is handy in this case, to save wire, to use the lead gas-pipe as return wire, especially if the battery is far from the lighter.

In this arrangement the tap has a spring which tends to turn it to a vertical position, and with a tooth which, interlocking in a pivoted piece D, keeps it in its horizontal position as soon as it is turned. To extinguish the gas the lever D is lowered, which enables the tap to return to its vertical position, that is to say, the gas is turned off.

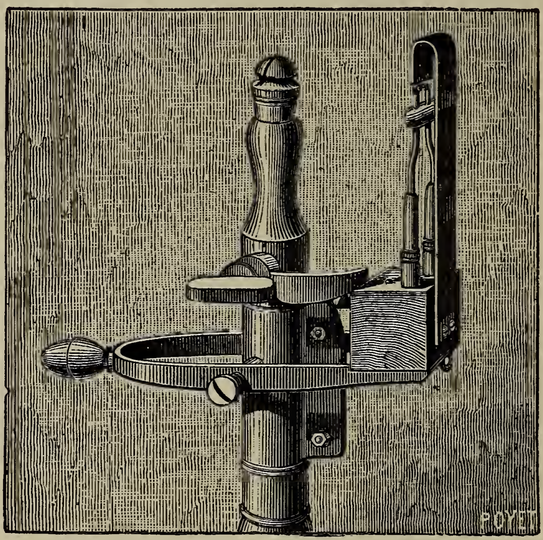
Another arrangement is that shown in Fig. 66. It is a gas-tap for an ordinary burner, batswing, Argand or Manchester, having a spiral fitted to the side. One end of the spiral is joined to the positive of the battery, the other to a small horizontal brass rod, which will be seen on the bottom of the figure. By opening the tap a slight escape of gas takes place near the platinum spiral, and at the same time a projection firmly fixed on the tap presses a small vertical metallic piece, bringing it into contact with the brass rod; the circuit is closed for an instant, the spiral glows and lights the gas, the flame rises and finally lights the burner. It is needless to add that by continuing the motion the contact breaks, in order not to tax the battery uselessly and to reclose the escape.

The Fiat-lux.—This consists of a fine platinum wire supported by a swinging arrangement in connection with the two poles of a battery of two or three Leclanchés. By pulling down the button on the left of the apparatus, shown in Fig. 67, either direct or by means of a small cord fixed to this button, it at the same time turns the gas on and brings the platinum spiral to it, which by closing the circuit becomes incandescent. When the gas is alight the apparatus is let go, the tap remains open, the spiral moves away from the burner, the circuit is again open, and the gas burns until it is extinguished by turning it off.

G

This arrangement is particularly suitable in all cases where there is a sudden need for a light, as a single action is sufficient to open the tap and to light the gas.

F:G. 67.



Portable Gas-lighters.—These are mostly based on the calorific properties of the spark produced by an induction coil, and the internal arrangements allow the use of a powerful battery, taking up very little space. The apparatus consists of a rod of a length to suit the height of the burner, to the lower part of which is fixed an ebonite tube an inch and a half in diameter and 8 inches in length. This tube divides into two parts, which are shown separately in Fig. 69, and incloses the battery and the coil. The battery is a chloride of silver cell, and is hermetically closed, and has a disc B and a brass rim C on the upper end which form the two poles; when the two parts are screwed together these make contact with the two springs B and C.

The battery is supposed to supply 25,000 lights before exhaustion. H is an ebonite tube inclosing and protecting the induction coil K, the secondary wire of which com-

municates with the brass tube L and a central insulated conductor M, the point of which is near to the end of the

FIG. 68.

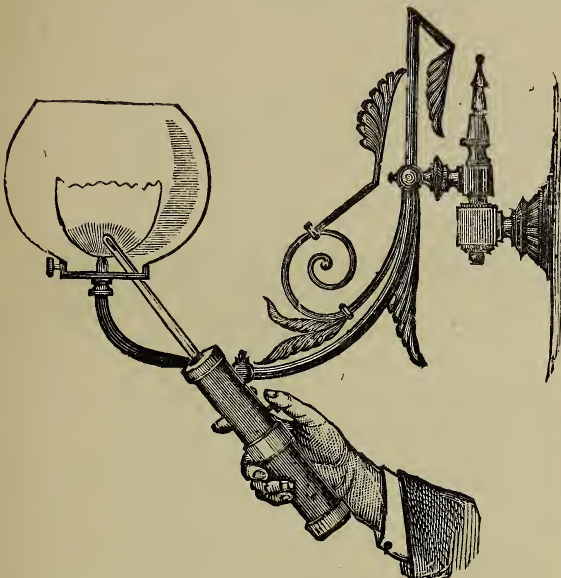
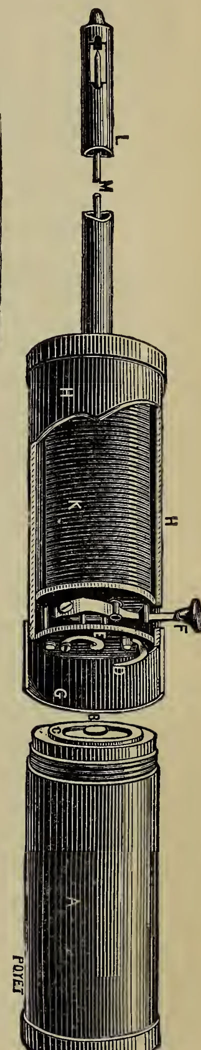


FIG. 69.



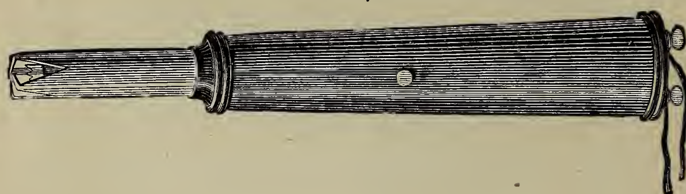
brass tube. The currents induced in this wire give a series of sparks between the tube L and the rod M, which light the gas when the end of the apparatus is brought near to the burner.

When the end of the tube L is brought near to the burner to be lighted, it is sufficient to press the button E from left to right, in order to develop a limited number of sparks sufficient to light the gas. The effect of the motion of the button F is not, as might be supposed, to close the primary circuit of the coil ; in fact, in its ordinary position, the trembler is some distance from its contact, and closing the circuit produces no effect ; the motion of F causes a mechanical displacement of the spring of the trembler, which vibrates for some seconds, and produces a definite number of contacts, giving rise to an equal number

of sparks. Owing to this arrangement, the expenditure of electric energy required for each lighting is limited, and on the other hand, the trembler is worked mechanically, when it would be unable to act if it were necessary for the current to do the work. The required vibration being obtained from the hand of the operator, the battery is saved this work, and lasts longer.

For gas stoves a movable lighter, as shown in Fig. 70, may be used.

FIG. 70.



The latest and perhaps the most remarkable form of gas lighter is one which, though it resembles in external appearance that shown in Fig. 68, is entirely different in principle. It is in reality a small static machine of the Wimhurst influence type, the plates being spun at great speed by pressing the button sharply. As no battery is used there is nothing to be consumed, and the whole thing being merely a mechanical contrivance, as long as the parts are not broken, it is an inexhaustible source of sparks sufficient to light the gas.

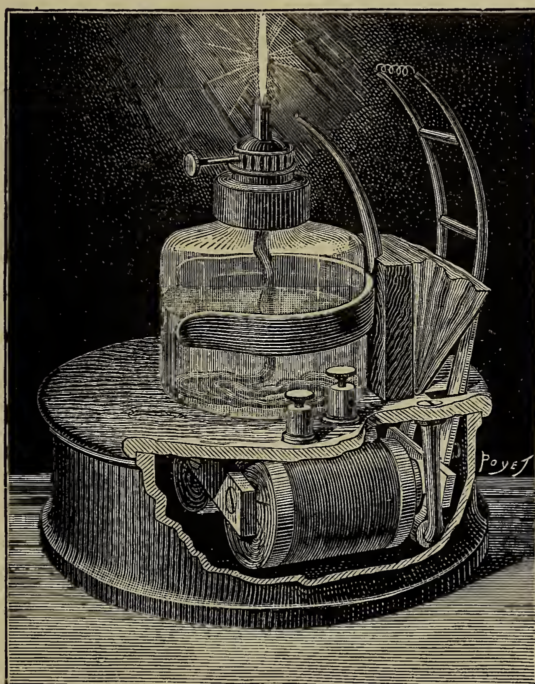
All these lighters act well, and render real services ; they may be considered a natural and indispensable adjunct to domestic electric bells.

Combined Lighters and Extinguishers.—To light a lamp at a distance when it is out, or to extinguish it when it is lighted, by simply pressing a button, sounds a difficult problem, but by means of a double system of electro-magnets, commutators, &c., somewhat complicated, this may be effected.

In the arrangement shown in Fig. 71, the spirit or petroleum lamp is placed on a stand inclosing a horizontal electro-magnet. The armature of this electro-magnet has two long

copper rods, to which a small platinum spiral is fixed ; these rods at the same time work a small bellows, to which is fixed a tube, the end of which opens near the wick of the lamp.

Fig 71.



By sending a current through the apparatus (four bell Leclanchés or two large surface cells are sufficient) one of the following two effects is produced :—

1. If the lamp is out, the current at the same time goes through the electro-magnet and the spiral ; the first attracts the armature and brings the spiral to the wick, setting it alight, but the bellows being acted upon before the spiral approaches the wick, it blows at a lamp which is not burning, which makes no difference, and when the current stops, the spiral resumes its original position, leaving the lamp lighted.

2. When the lamp is burning the current passes as before, but the bellows take effect this time, and the lamp is blown out; if the contact is not prolonged sufficiently to give the spiral time to relight the lamp, the armature resumes its original position, leaving the lamp extinguished.

The form of the apparatus permits of its being adapted to a hanging lamp in a bedroom, ante-room, or other place where the light is only required at irregular and unequal intervals.

FIG. 72.

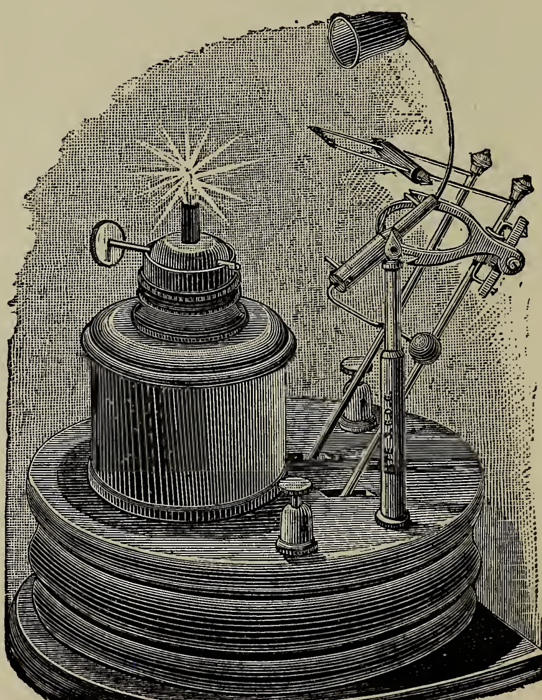


Fig. 72 shows a novel arrangement. An electro-magnet inclosed in the stand brings the platinum spiral to the wick. The extinguisher, balanced by a counterpoise, swings on a horizontal axis. The support of this extinguisher has two small pins acted upon alternately by two notches on an oval-shaped piece, fixed on one side of the movable rods.

In the position shown in the figure, on first closing the circuit, the upper notch pulls the extinguisher, but the course of the rods carrying the spiral is limited so that the spiral does not hit the extinguisher, which would spoil it. The next time the current passes, the lower notch lifts the extinguisher up again, while the spiral is brought near to the wick, and lights it.

It is convenient to work these combined lighters and extinguishers not by a contact button, but by a pull, which is easier to find in the dark.

CHAPTER VII.

Domestic Electric Lighting.

Of all the domestic uses to which electricity may be put, without contradiction, lighting is most tempting to amateurs, and the desire increases every day, as the lamps get more perfected and the numerous and incontestable advantages of this mode of illumination are appreciated. The most serious obstacle to the universal adoption of the electric light (apart from the question of price which for a small installation is and must be very high) is the inherent difficulty of producing the electrical energy. When the distribution of electricity to every house is an accomplished fact, the use of the electric light will become general even if for an equal light a higher price has to be paid than for gas. This extra expense will be largely recovered by the less amount of disagreeable heat, decrease of danger from fire, a steadier light, a more breathable atmosphere, no more blackened ceilings, &c.

In spite of the inherent difficulties of the production of electrical energy in sufficient quantity for lighting, many private persons have got over these difficulties and have installed for their own use regular model manufactories of electricity sufficient to satisfy their daily or intermittent wants. We will rapidly explain the principal things necessary for an installation, such as motors, machines, batteries, accumulators, lamps, and accessories.

Prime Movers.

All motors are not equally suitable for private lighting. Steam engines require too much attention and can only be used advantageously for installations of large size, and are

therefore beyond the limits of the present work. Hot air engines are also not suitable. This only leaves water motors, applicable only in few cases, and gas engines.

If a sufficient fall of water be obtainable, high speed turbines are the very best motors possible for driving dynamos. Simply turning a tap starts and stops them, but unfortunately it does not often happen that water power is available and therefore we will not go further into this here.*

Gas Engines.—The gas engine possesses many of the qualities necessary for domestic electric lighting, and in this country, America, and the Continent very numerous installations are now running. Preference is almost universally given to the Otto gas engine shown in Fig. 73.

A gas engine consists of a cylinder in which a piston works ; a suitable mixture of air and illuminating gas is introduced into the cylinder and this mixture is set alight, either by electricity as in the old Lenoir engine, or by a gas jet as in the Otto, Clarke, and Bishopp.

The high temperature produced by the combustion of the mixture expands the gas and the piston is pushed with a force depending upon the composition of the mixture, its volume, and upon its more or less complete and efficient combustion. When the expanded mixture has produced its effect it is allowed to escape into the exhaust, a fresh mixture is introduced into the cylinder, which is in its turn exploded, and so on.

This is the principle : it is simple, but what difficulties in application ? These difficulties have been more or less surmounted, especially in the Otto and Clarke engines.

The Machine.

The most convenient apparatus for experiments of short duration is the hand or treadle Gramme, Fig. 74. If it is desired to use it to charge a few accumulators with, and a small hydraulic or gas motor is at hand, a pulley and belt are

* I can speak from experience of the great advantages of using water power by means of turbines to drive dynamos, and thus obtain light from a natural source, costing nothing. I have installed hundreds of lamps off turbines.—C. J. W.

easily fitted. For charging accumulators particularly, the magneto-electric machine has this advantage, that a reversal

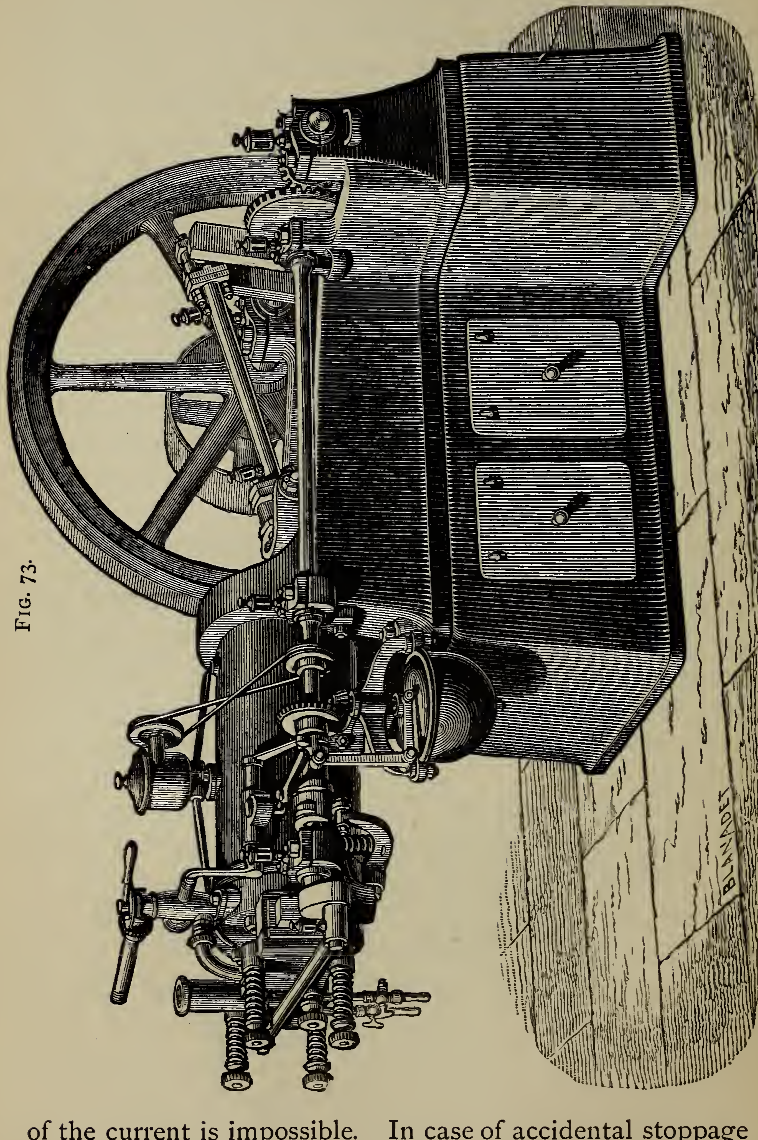


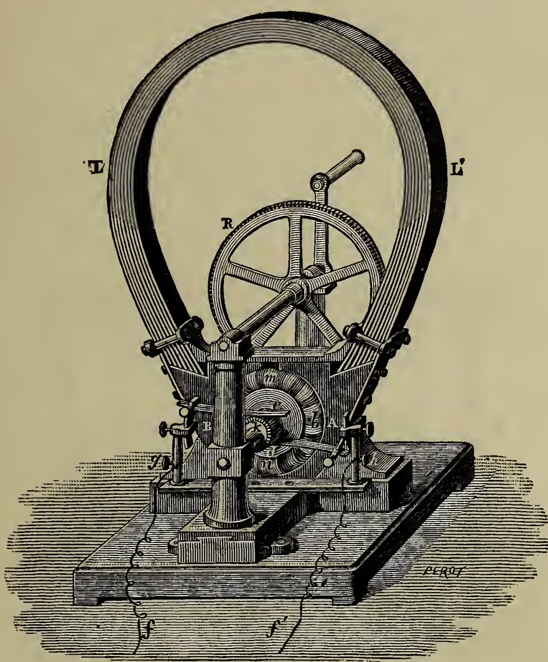
Fig. 73.

of the current is impossible. In case of accidental stoppage it will be sufficient to insert in the charging circuit an automatic

contact-breaker which breaks the circuit before the accumulators can discharge themselves through the machine.

For more important installations dynamos must be used, that is to say, machines where the magnetic field in which the armature revolves is an electro magnet and not a permanent magnet.

FIG. 74.

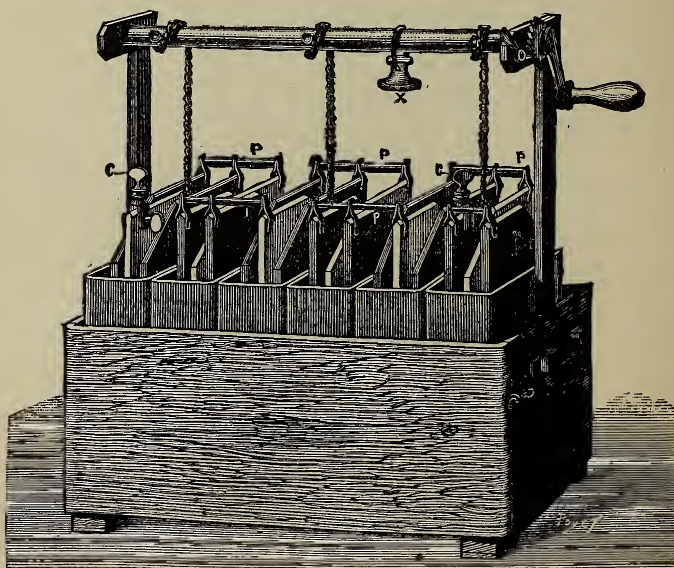


For full description of dynamos, their construction, theory and practice, see works devoted to the subject. We will here only mention that shunt dynamos are more especially suitable for charging accumulators, while compound-wound dynamo machines are more especially suitable for direct lighting. If, for example, our installation consists of 60 lamps, by means of a compound machine it is possible to have a single lamp alight or the whole sixty, and to light or extinguish any number at pleasure, without interfering with the action of the others.

Heavy Current Batteries.—With reference to primary batteries for continuous work, we would refer the reader to what we have already said (see p. 17) about some forms of battery, but we will now refer more especially to some new types which are intended and have been used exclusively for electric lighting, but the question of cost and attention required must not be too closely criticised by those who, though willing to pay for the luxury of the electric light, only require a small number of lamps, and can therefore not satisfactorily or economically use dynamos and engines.

Bichromate of potash Battery. Trouvé's Type.—When designing the battery represented by Fig. 75, Trouvé started with the idea of producing a source of electricity

FIG. 75.



capable of giving light for some hours (four to eight according to the number of lamps in use) by means of incandescent lamps suitable for this purpose, and requiring not more than 12 to 14 volts E.M.F., which enables a very fair amount of light to be obtained from two batteries, the total weight of which does not exceed 140 lbs.

Each battery consists of an oak trough holding six ebonite jars, which contain the liquid of each element. The zincs and carbons, coupled up by movable connections, are mounted on a windlass, enabling them to be immersed or withdrawn from the liquid at pleasure, and to regulate the current by dipping the electrodes more or less into the liquids, that is to say, by varying the internal resistance of the battery and its active surface. A wooden stop prevents the electrodes from coming completely out of the jars; on removing this stop and again turning the windlass they rise completely out of the jars, so that these may be removed for emptying and refilling.

The front of the trough is therefore furnished with a hinge enabling it to be opened and the jars taken out without disturbing the electrodes. These consist of a zinc plate and two carbons, coppered on the top. The zinc has an indentation which serves to fix it to the metal rod covered with india-rubber, which supports the electrodes. This arrangement allows the zincs to be very quickly taken out to amalgamate or replace them.

The total weight of a battery of six cells is about 34 kilos., divided as follows :—

	Kilos.
Six zincs	7·68
Twelve carbons	5·46
Six ebonite jars	1·62
Contacts	0·60
Oak case	3·00
Iron mountings	2·30
Liquids	12·80
Total weight	33·46

The composition of the liquid for a battery is as follows :—

	Kilos.
Water	8·0
Pulverised bichromate of potash ..	1·2
Sulphuric acid	3·6
Total	12·8

and is prepared as follows :—

The powdered bichromate of potash is thrown into the water, and after being stirred up the sulphuric acid is added

very slowly, stirring all the time; the mixture heats by degrees, and the bichromate, once dissolved, remains clear and does not crystallise in cooling. The preparation takes eight to ten minutes. Care must be taken not to use a wooden stirrer, which would be quickly carbonised, thereby exhausting uselessly part of the solution.

Time must be given for the solution to cool before putting it into the battery.

Two Trouvé batteries in tension freshly charged with the above solution have given the following results :—

1. A constant current of 8 ampères, during four hours and a quarter, taking care to lower the zincs from time to time to increase the active surface as the liquid became exhausted.

2. A decreasing phase of an hour and twenty-five minutes, during which the current fell very regularly from 8 to 5 ampères, when the experiment was stopped.

The zincs, weighed before and after the experiment, showed a total consumption of 11,463 grammes, or an average of 122 grammes per cell. The theoretical consumption should have been 53 grammes per cell, according to the electro-chemical equivalents and the total quantity of electricity furnished by the batteries.

The twelve elements therefore supplied a constant disposable electric work of 13·5 kilogrammetres per second for four hours and a quarter, and work of about 9 kilogrammetres per second for about an hour and a half; a total of 253,350 kilogrammetres, or nearly one horsepower-hour.

We do not give the candlepower-hours as these have no real value, no notice being usually taken of the efficiency at which the lamps are burned, and if to-morrow a substance should be discovered more refractory than carbon, and possessing its electrical qualities, it will then be possible to double, quadruple, or increase tenfold the light without increasing the expenditure of electrical energy. The number of candle-hours furnished by the battery would be doubled, quadrupled, or increased tenfold without the batteries consuming an atom less or producing a foot-pound more.

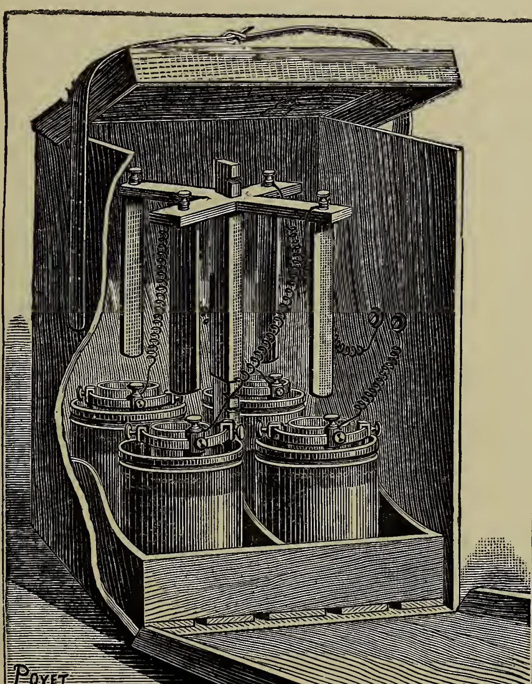
In fact, it is shown that the work that two newly charged

Trouvé batteries in tension can produce is 13·5 kilogrammetres per second for four hours and a quarter, and a decreasing delivery for about one hour and a half, during which the current fell from 8 to 5 ampères, the total available energy furnished being about one horsepower-hour. This electrical energy costs :—

	Grammes.
Zinc	1·360
Bichromate of potash	2·400
Sulphuric acid	7·200

in addition to amalgamation, labour, depreciation, and other small expenses common to all systems.

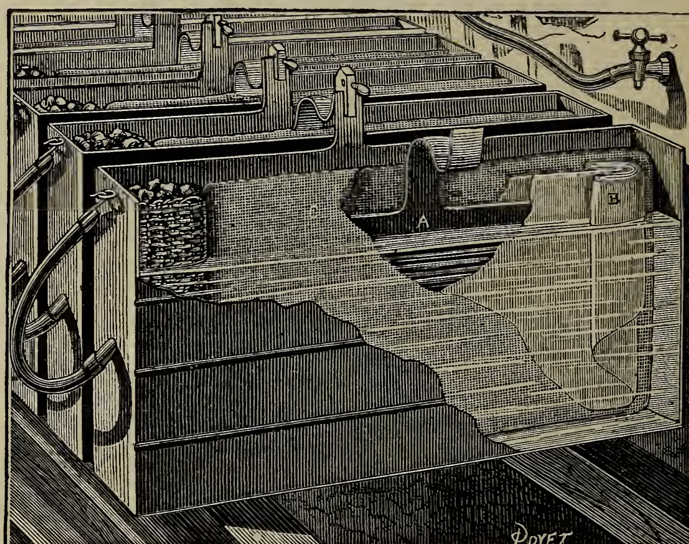
Fig. 76.



Radiguet's Battery.—This battery and its arrangements and mode of construction will be easily understood from the drawing Fig. 76.

Reynier's Battery.—This is a modification of the Daniell cell, and its appearance is shown in Fig. 77. The containing vessel is of copper and acts as positive electrode. The zinc, in rectangular form, is covered with a porous pot of parchment paper; the zinc nearly entirely fills up this

FIG. 77.



porous cover, and a thin piece of cloth sewn over all protects the paper.

The sulphate of zinc is at first formed by local action at the expense of the electrode and of a small quantity of sulphate of copper which gets to it through the cover. The cell, therefore, gets itself into its normal working condition, and the excess of sulphate of zinc which is ultimately formed by the closing of the circuit, diffuses itself towards the external compartment.

The action of osmose is sufficient to keep up the supply, and the harder the battery is worked the more the action of osmose brings up the supply of sulphate of zinc.

To renew the sulphate of copper in the outer cell the india-rubber tube with which each cell is provided is lowered, in

order to allow part of the exhausted liquid to run out; ordinary water is then added through these tubes, and sul-

Fig. 78.

phate of copper is put into a wicker basket hung on the upper part of the containing vessel.

In order to reduce the internal resistance, a mixture of neutral or acid salts, soluble and cheap, may be added to the cells, such as chlorides and sulphates of potassium and sodium, sulphate of ammonia, nitrate and bisulphate of soda, &c.

Once a month the battery must be taken to pieces to change the zincs and to clear away with a wooden knife the lumps of copper which are deposited, the value of which is a set-off against general expenditure.

For cells 16 inches by 8 inches by 2 inches, the constants are:—

$$E = 1{\cdot}07 \text{ volt.}$$
$$R = 0{\cdot}14 \text{ ohm.}$$

The expenditure per twenty-four hours of work is about:—

Sulphate of copper	400 grammes.
Zinc	100 „

with a deposit of copper of nearly 90 grammes.

Mr. Reynier at his own house uses a battery of sixty-eight small cells. Fig. 78 represents it in its actual position under the windows of the drawing room in a small court which separates the house from the street. This battery is used for the formation of accumulators, for work in the laboratory, and for lighting the house as required.

Accumulators.

This is the name given to any apparatus capable of storing energy or work, in any shape, which may afterwards be given out again at will. An electric accumulator then is an apparatus which absorbs energy in the form of electricity (the charging current), stores it as chemical energy, and subsequently gives it up again in the form of electrical energy (discharging current), available at will for lighting, motive power, &c.

An electric accumulator is nothing more than a reversible battery, that is to say, a battery capable of being indefinitely regenerated by sending a current through it in the opposite direction to that which it itself produces, thereby recombining in their original state its component substances, and thus a fresh quantity of energy may be produced, limited in each

case by the nature and quantity of active materials, as well as the duration and power of the charging current.

Theoretically, every battery, the chemical action of which does not set free gases which escape and are lost, is reversible and capable of being an accumulator.

Practically, lead alone answers the purpose of alternate charges and discharges, as was demonstrated by Planté in 1860.

Accumulators may also act as transformers, that is to say, heavier currents than those of the original source may be obtained from them for a proportionately shorter time, or inversely, we may have smaller currents, lasting longer than the original source.

For example, with 800 small Planté cells charged in quantity by two Bunsens and subsequently coupled in tension, a Geissler tube may be illuminated direct, and all the so-called static electrical effects may be reproduced.

Fig. 79.

On the other hand, small accumulators have been constructed by a process analogous to that of dry piles and charged in series by a Holtz machine; by recoupling them subsequently in quantity, effects of the same nature as those furnished by so-called dynamic electricity may be obtained.

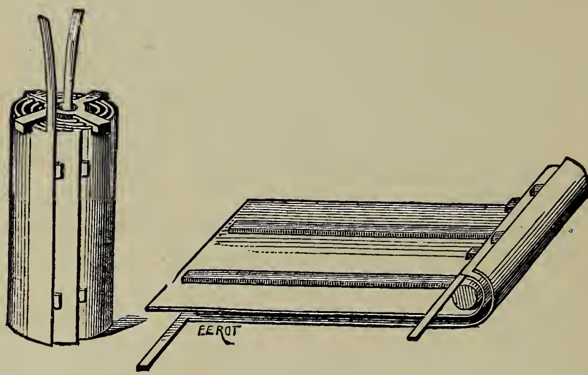
Construction of an Accumulator.—The most simple way to construct an accumulator is to roll two long and broad lead plates into a spiral, separated by a piece of thick cloth, Fig. 79, and then to plunge them into a jar full of water, acidulated with sulphuric acid in the proportion of 2 in 20 or 25 by bulk. This is the accumulator constructed by Planté in 1860.

The cloth has the disadvantage of rotting away in time and also of increasing the internal resistance of the accumulator.

It is better to separate the plates by narrow strips of india-rubber which do not rot in the acidulated water and only cover a small portion of the surface of the electrodes.

To construct these cells, take two narrow strips of india-rubber, Fig. 80, about half an inch broad and a quarter of an inch

FIG. 80.



thick, to prevent the plates touching. The prolonged contact strips should be placed at opposite ends of the plates to avoid short-circuiting them, and to equalise the distribution of the primary currents on the surfaces of the electrodes.

The lead plates, thus separated by two or three pairs of indiarubber bands, are wound on a wooden or metal cylinder.

It is well to place two small indiarubber bands lengthways of the roller so as to thoroughly separate the edges of the two lead plates.

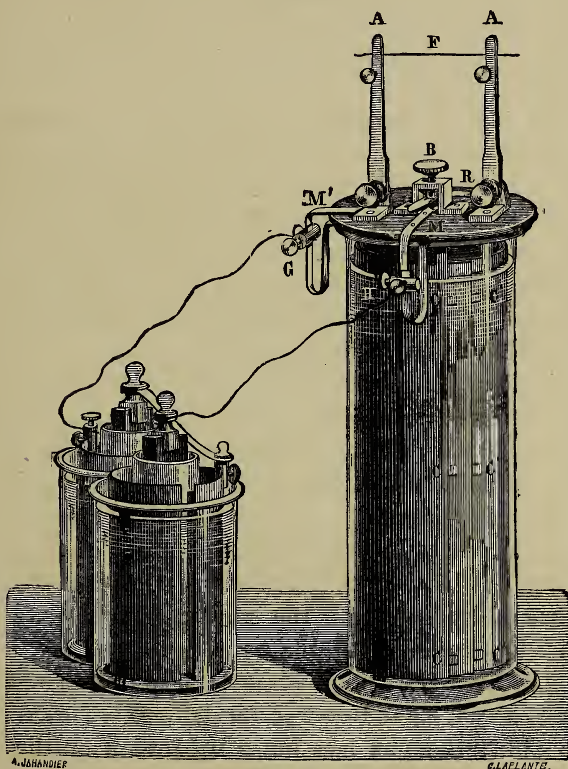
The rolling up effected, the internal roller must be carefully withdrawn, and to give stability to the whole system, the spirals may be kept in their place by means of small gutta-percha cross-bars fixed on when softened by heat. The couple thus constructed is then put into a cylindrical glass jar filled with water acidulated with 1 in 10 of sulphuric acid.

Fig. 81 shows a cell constructed as described.

The containing glass jar is covered with a disc of hard rubber, to which are fixed the terminal pieces. The ends of the two lead plates are, by means of the binding screws G

and H, both in contact with a small primary battery of two Bunsen cells and with the copper strips M M′. The strip M is fixed below another copper strip R, its prolonged end making a spring which may be pressed down by the thumb-screw B, and the strip M is then in communication with A.

FIG. 81.



The strip M′, on the other hand, is always in contact with the clip A′, and between these two clips are placed the metallic wires to be reddened or melted by the current. To these two clips may be attached the wires coming from any other apparatus through which it is desiıed to pass the current.

Chemical Action produced in Lead Secondary Cells.—When a secondary cell of large surface is new, and

the current from two Bunsen cells is passed through it, oxygen appears almost immediately on the one plate, and it is not long before this is covered with a very fine coat of peroxide of lead. On the other hand, the hydrogen, after having reduced the slight coat of oxide with which the lead may be covered owing to exposure to the air, will soon make its appearance on the other plate, and if after some seconds the secondary current produced by the apparatus be tried, it will be found from the crispness of the spark that it is already very energetic.

During the discharge the oxygen on the plate, which during the passage of the charging current was negative, has slightly peroxidised this plate, at the same time that the peroxide formed on the other plate during the passage of the primary current was reduced by hydrogen. After the first experiment, therefore, the two plates are covered with a slight coat of oxide and of reduced metal, which facilitate the action of the charging current when again turned on.

The lead plate which during the first passage of the charging current was negative is, as will be seen, covered with a coat of oxide after the discharge has taken place. It results therefrom that if the charging current is again passed, the first portion of hydrogen will be applied in the reduction of this coat of oxide, instead of the thin coat due solely to exposure to the air as happened previously. In consequence, the appearance of hydrogen on the surface of this plate will be more retarded than the first time.

The first portion of the oxygen set free on the surface this time meets a coat of reduced peroxide or subdivided metallic lead, on which the gas has more hold than on the original lead plate; the gas is more easily absorbed, and a delay is also noticed in the appearance of oxygen on the plate, a delay which corresponds to the time necessary to oxidise again the coat of reduced lead on the surface.

When the current is again discharged, the preceding phenomena are reproduced, and after these operations have been renewed a very great number of times, it will be seen that the surfaces of the plates are in a more favourable state

for oxidation or reduction; the coats of oxide alternately formed and reduced become denser, and the secondary effects resulting therefrom last longer and are more energetic.

It will, in fact, be noticed that the more primary current a secondary cell can usefully receive, the longer is the duration of the secondary current. All the work of the battery is thus accumulated in the shape of oxidation of lead on the one hand, and on the other in the reduction of oxidised lead produced by the previous discharging current. When, in a well-formed cell, the gases commence to appear and escape, it is a sign that the battery can effect no more useful work in storing energy.

A well-charged secondary cell will furnish a discharge which depends on the size of the plates, the thickness of the products, and finally on the external resistance of the circuit.

The discharge is very constant as long as the battery holds stored electricity in the form of chemical energy.

In the same way as a very large vessel holding a great quantity of liquid of very slight depth, may furnish for a long time through a small orifice a nearly constant flow, ceasing suddenly as soon as the liquid gets to the level of the orifice, so a secondary battery of great surface only diminishes in strength a short while before entirely stopping its supply.

The initial E.M.F. of a well-formed secondary cell reaches nearly $2\frac{1}{2}$ volts, which explains why at least three Daniells or two Bunsens are necessary to charge it completely.

The low internal resistance of the cells, which varies between $\frac{1}{20}$ and $\frac{1}{5}$ of an ohm, explains the strength of the current furnished. Planté cells can also be charged by laboratory Gramme machines; but in that case the speed must not fall below a certain rate, or else the battery will discharge itself uselessly through the machine. To avoid this an automatic maker and breaker of the circuit may be used, which cuts out the secondary battery as soon as the E.M.F. falls too low to charge it, and replaces it in the circuit as soon as the E.M.F. is sufficient.

Secondary batteries keep the accumulated charge for a long time. Thus a well-formed and well-charged secondary

battery can still make a platinum wire $\frac{1}{2}$ millimetre in diameter glow more than a month after charging.

According to Planté the secondary battery gives a return of 88 to 89 per cent. of the energy put into it, but this is never reached in practice.

The formation of a secondary battery is a long and costly operation, and many plans have been devised to reduce this. Among them Planté discovered that the formation of the elements is accelerated by increasing the temperature of the electrolyte either before or during the action of the charge. But practically this presents many difficulties.

A better plan is to soak the plates from 24 to 48 hours in a strong nitric acid solution. They are then thoroughly washed, fitted in the cells, filled with the proper electrolyte of weak sulphuric acid and water, and submitted to the charging current.

Notwithstanding a dissolution of a portion of the lead, the thickness of the plates is not materially diminished, but the acid produces a sort of metallic porosity, so that the chemical action of the current is not limited merely to the surface of the lead ; it acts also internally, creates new molecular intervals and facilitates in consequence the action of the charging current.

Secondary cells so treated will, in a week, after three or four reversals of the charging current, give results which without the previous nitric acid process, they would only give after several months of formation. It will therefore be of interest to amateurs who desire to construct and form their own accumulators, to know this process.

Faure's Accumulator.—Faure's secondary battery is directly derived from the Planté battery; his electrodes are of lead, and are plunged in water acidulated with sulphuric acid ; but its formation is more thorough and quicker. In the Planté battery the formation is limited by the thickness of the lead plates. Faure quickly gives his batteries an almost unlimited power of accumulation, by covering the electrodes with spongy lead, formed and retained in the following way :—

The two plates are each covered with minium or other insoluble oxide of lead ; they are then covered with felt, placed close together on a vessel holding acidulated water.

If they are of great length they are rolled spirally, as in the Planté cell. To form them a current is passed through them, which brings the minium to the state of peroxide on the positive electrode, and on the negative to reduced lead. As soon as the whole mass has been electrolysed, the couple is formed and charged. When it is discharged the reduced lead oxidises, and the peroxided lead is reduced until the battery is exhausted. It is then ready to receive a new charge of electricity. We only describe it here as a matter of history, as this type is now abandoned in favour of the Faure-Sellon-Volckmar accumulator. The perfections to which the Faure accumulator has been brought, and which have given rise, after many transformations, to the apparatus known to-day as the F. S. V. accumulator, consist in :—

1. Doing away with the felt, which does not last long in the acidulated water.

2. In the use of perforated lead plates in the shape of a grating, holding the oxides of lead, which the current on the one hand oxidises, and on the other reduces.

The reduced lead and the peroxidised lead are therefore in the form of small blocks, round in the original model, square in the actual practical type, surrounded on four sides by a network of lead conductors, which place them in more intimate connection with their respective electrodes than on the original Faure type, in which the oxides were merely applied to the surface of the lead plates.

There are three types current.

1. The laboratory type, weighing from 18 to 24 lbs. in glass jars for amateurs, which may be used for lighting, electro-deposition, &c., on a small scale.

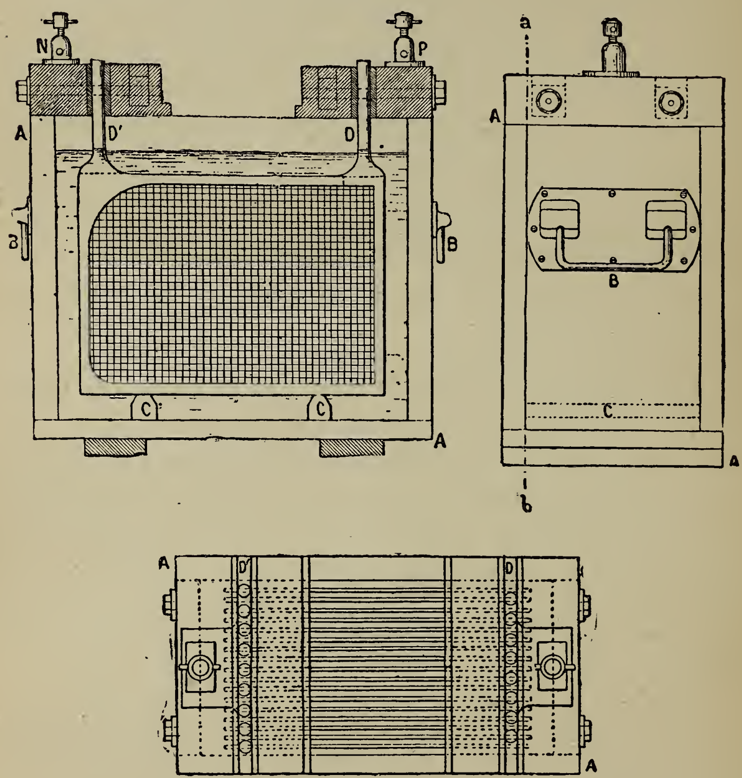
2. The tramway type, weighing about 65 lbs., intended especially for movable installations, such as tramways, tricycles, and electric navigation.

3. The lighting type, weighing about 120 lbs., the use of which is restricted to fixed installations.*

* These sizes and denominations only apply to French manufacture. The F. S. V. accumulators made in England by the Electrical Power Storage Company vary somewhat in size and denomination from those referred to here.

Fig. 82 shows the tramway type in elevation and section. It consists of a rectangular case of tarred wood, holding 17 lead plates, each in the form of a grating terminating in a lead strip which serves as terminal.

FIG. 82.



Nine plates are joined on one side of the box in quantity to form the negative pole, and the other eight on the opposite side to form the positive pole. The joints are made by pinching the projecting strips between two lead plates in communication with the terminals N and P. The plates are kept apart by indiarubber rings. The brackets C are for the purpose of leaving a space at the bottom of the boxes where any particles of reduced or oxidised lead detached from the

electrodes may fall and accumulate without making a short circuit between the plates.

The mean weights of a tramway accumulator are divided as follows :—

	Kilos.
Tarred wood case, lid, handles, and terminals	6·0
Acidulated water of 1 in 10	6·5
Lead plates and oxides	16·8

The gaps of the positive and negative plates are respectively filled up with litharge and red lead or minium, which is previously made into a paste and spread on the plates and then by pressure all the holes are equally filled up.

The plates thus prepared are fixed in the cases and submitted to a formation which consists in passing a current through them proportionately powerful to the surface of the plates, the duration of which is about 100 hours. The number of 100 hours is not absolute, as after this formation the accumulators still gain in capacity with each new charge as they are used in consequence of the gradual attack of the lead supports.

The accumulators for lighting purposes differ only from the tramway type in weight and size ; they are proportionately heavier in order to obtain greater solidity and lasting power.

Storage Capacity.—All experiments with accumulators go to show that the total recoverable energy from a given weight of accumulators, diminishes as the work demanded in a given time is increased, that is to say, the greater the current taken out, the less will be the total output.

From recent experiments with F. S. V. accumulators, 15 ampère-hours per kilogramme of plates have been obtained with a mean useful potential of 1·9 volt at the terminals, that is, 10 ampère-hours per kilogramme of the total weight, taking the weight of both cover and liquid at 50 per cent. of that of the lead plates.

A horsepower-hour of electrical energy is thus obtained from a weight of 40 kilogrammes or about one electrical horsepower per 88 lbs.

The capability of accumulators in which lightness is not so

much an object, is of course less, and the weight of material necessary to produce one electrical horsepower-hour may reach 170 lbs.

Efficiency and Duration of Accumulators.—It is of interest to know, when accumulators are used, how the losses sustained in the different transformations are apportioned from the moment the energy is furnished by the prime mover (steam, water, or gas), up to the moment it is again given out in the form of mechanical work. The following figures apply under ordinary conditions:—

Mechanical work absorbed by the charging machines	100
Electrical energy furnished by these machines, and available for the charge $0 \cdot 7 \times 100$	70
Only about $0 \cdot 9$ of the quantity of electricity furnished by the charging machines is obtainable from the accumulator, and the pressure or mean E.M.F. of discharge is only $0 \cdot 7$ of the mean charging E.M.F.; the available electrical energy is therefore only $0 \cdot 9 \times 0 \cdot 7 = 0 \cdot 63$ of the energy of the charge supplied to the accumulators.	
It results therefrom that the available electrical energy is equal to $0 \cdot 63 \times 70$ of the initial motive power = ...	44·1
Finally, when this electrical energy is transformed back into mechanical work, only $0 \cdot 7$ or $0 \cdot 7 \times 44 \cdot 1$	30·8

is obtained, that is to say, about 31 per cent. of the initial mechanical work supplied by the prime mover. 100 horsepower-hours must therefore be expended in the motor which drives the charging machines in order that the accumulators may supply 31 available horsepower-hours for locomotion or any other application.

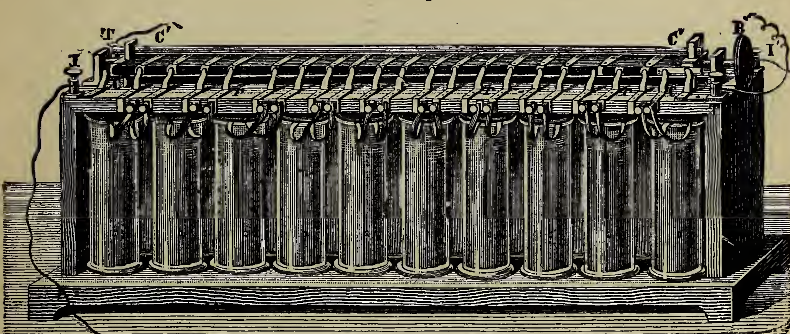
According, therefore, as the available electrical energy is utilised direct or transformed into mechanical work 44 or 31 per cent. of the available initial work is obtainable for industrial purposes.

No reliable figures respecting the duration of accumulators are so far available. The lighting apparatus installed permanently, charged and discharged systematically, will last very much longer than batteries for vehicles subject to rapid charging, irregular use, and much knocking about. Planté's accumulators of simple lead plates seem to offer greater guarantees in this respect than the F.S.V. accumulators.

Applications.—In spite of the loss which must be suffered by means of the intermediary of accumulators they offer great and numerous advantages. Foremost among their advantages, accumulators are most useful for purposes of instruction whether on the lecture table or in the laboratory, not only for the studies to which they give rise, but also for the many electrical operations to which they so easily lend themselves.

Fig. 83 represents 20 Planté cells arranged for this purpose. At the upper part is a commutator which in one position couples the 20 cells in quantity and in another puts them

FIG. 83.



all in series. In the first case all the external electrodes are joined to one metallic plate and all the internal electrodes to another, in such a way that the entire apparatus is like a single cell of great surface; the charge is then effected; 2 Bunsens are sufficient, and in a longer or shorter time according to their dimensions and the extent of the lead surfaces they are fully charged. In the second case the external electrode of each element is put in communication with the internal electrode of the succeeding cell and the apparatus is made a veritable battery of 20 cells, and under these conditions the battery may be discharged, the current available being equal to 30 Bunsens of very large surface.

In fixed installations where the accumulator has to act the part of a fly-wheel, regulator, or receiver, it may also render

efficient service, for example in lighting applications it gives more constancy and steadiness to the light and renders accidental total or partial extinction impossible, which in a theatre, for example, would be a veritable disaster.

Accumulators also enable more light to be obtained for a time than by using direct the disposable power, this result being obtained by expending in 4 or 5 hours all the work produced by the engine in 20 hours.

Accumulators may also be used as movable reservoirs of electrical energy in applications where expense is a secondary matter.

For example, assemblies, balls, and soirées may be lighted by means of incandescent lamps fed by accumulators brought to the house from the factory in carts. The cost of an installation of this nature is not so much more than that paid for other modes of temporary lighting that it cannot be difficult to make it pay in the same way as similar hirings of marquees, chairs, flowers, &c.

We may also refer to pleasure boats, electric tricycles, and small luminous jewels for which accumulators are or soon will be perfectly applicable and to which we will further allude presently.

Electric Lamps.

The amateur electrician can only make use of the arc light in exceptional cases; the only electric lamps suitable for him are the carbon incandescent lamps. All these lamps, which vary considerably in shape and size, have a filament of carbon inclosed in a glass globe, exhausted as much as possible of air to prevent the combustion of the carbon. Almost any candle power and resistance may be obtained, and their price is at present 5*s.* each.

We cannot here undertake to describe their manufacture, which is a complicated and difficult operation. Besides, it is very easy to procure them at present, and we advise those who require them simply to buy them instead of trying to make them.

The characteristic point of incandescent lamps is the

nature of the filament. Edison uses carbonised bamboo, Maxim cardboard, Swan cotton, &c.

When buying an incandescent lamp the following three points are important to know :—The normal luminous power ; the amount of current in ampères which furnishes this luminous power ; the necessary potential difference at the terminals of the lamp in volts.

The least known and least correct figure is the luminous power of the lamp. Manufacturers of lamps and batteries have the bad habit of over-estimating the light produced. The possibility of forcing the lamps by increasing the current, added to the different standards in use, explains to a certain extent these errors. It is certain, however, that the progress made within three years in the manufacture of incandescent lamps, has doubled the light which a lamp for a given consumption of electric energy under normal conditions can supply. Normal conditions we call those when the lamp gives a sufficiently white light, lasting a long time without the filament breaking through gradual disintegration.

When the filament is broken the lamp is useless. The duration or life of lamps depends, everything else being equal, on their being used at a normal state of incandescence. The one is shortened by increasing the other, and conversely. Practically a mean must be adopted, the value of which it is difficult to indicate exactly. It may, however, be conceded that a lamp, the filament of which can be clearly distinguished when incandescent, may, from the point of view of luminosity, be traversed advantageously by a stronger current. A lamp, on the other hand, the filament of which cannot be distinguished is too much forced. Practically a lamp should not be run higher than where the shape of the filament begins to disappear.

In lamps of small dimensions, this critical point is often exceeded and thus they last but a short time. Lamps of medium size last with proper management from 500 to 2000 hours. Lamps have been known to last 4000 hours ; others, on the contrary, are rendered useless within a few hours or even minutes.

It will be seen within what wide limits the life of a lamp varies and the reason thereof will be well understood.

As we have now sufficiently defined what must be understood by normal power and proper management of a lamp, let us examine how the constants C and E of an incandescent lamp vary under these conditions.

The consumption of a lamp is calculated in watts or in volt-ampères. A lamp of which

$$C = 1 \cdot 2 \text{ ampère}$$
$$E = 50 \text{ volts}$$

is a lamp of $1 \cdot 2 \times 50 = 60$ watts.

The value of C depends upon the size of the filament; it varies between 0·4 and 2·5 ampères in ordinary lamps. The value of E depends at one and the same time on C and on the length of the filament. For electric jewels small lamps are constructed which only require 2 volts and act with a single accumulator; while Edison lamps, A type (16 candles), require 100 volts, and Swan lamps, 20 candle-power, from 41 to 120 volts as desired. A useful lamp for the amateur electrician is a Swan lamp of five candles, supplying a light sufficient for work in an office, if the light be reflected down by means of a shade. The E.M.F. required may be 10, 15, or 20 volts and the current 1, 0·66 and 0·5 respectively, thus consuming 10 watts.

A type of Swan lamp much employed in small installations is that equal to an ordinary gas-jet and may be had of 10, 15, 20, 25, 30, and 50 volts with current in proportion, the energy required in every case being 20 watts. The horse-power being equal to 746 watts, it will be seen that with one horse-power of available electrical energy it will be possible to supply 37 such lamps. With good dynamos this means from 25 to 30 lamps per actual horse-power supplied to the driving shaft. An Otto gas engine of three and a half horse-power is quite sufficient therefore for an installation of 100 such lamps.

ACCESSORIES.

The most important detail in fitting up a lamp is the holder, and to find a good lamp-holder is not an easy task. It should be solid, well insulated, and convenient to handle both for cleaning and for replacing a lamp.

Fig. 84 shows a very simple and rough form; it consists of a brass wire A, coiled to make a ring, in which the neck of the lamp fits; in the upright part of this wire is a curl which gives it the necessary elasticity; the platinum loops of the lamp are fixed to the hooks B B. The whole is fitted to a wooden socket C, which may be screwed into an ordinary chandelier or in place of a gas burner.

FIG. 84.

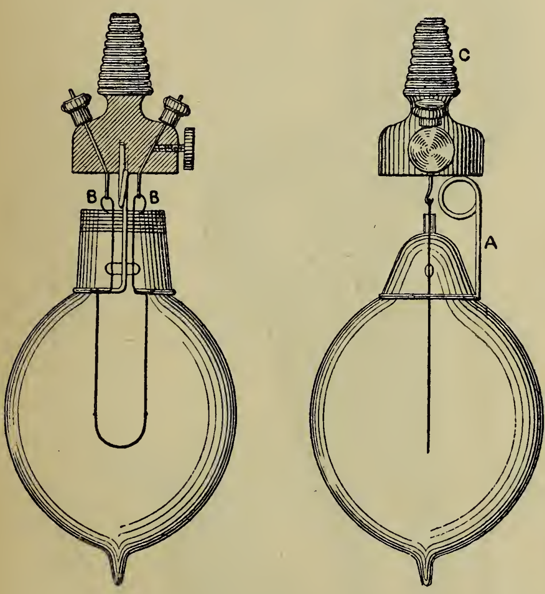
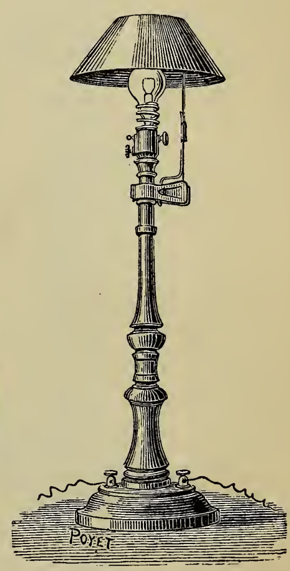


FIG. 85.



Sometimes a small switch is added to light or extinguish the lamp at pleasure.

Fig. 85 shows another and more usual holder fitted to a movable standard with a shade. If a more ornamental support is desired, Trouvé's chandeliers may be used, Fig. 86

FIG. 86.

or 87, and as will be seen these combine both the electric light and ordinary candles in one fitting.

Of course these designs may be multiplied indefinitely, and any of the regular makers supply many varieties both

FIG. 87.

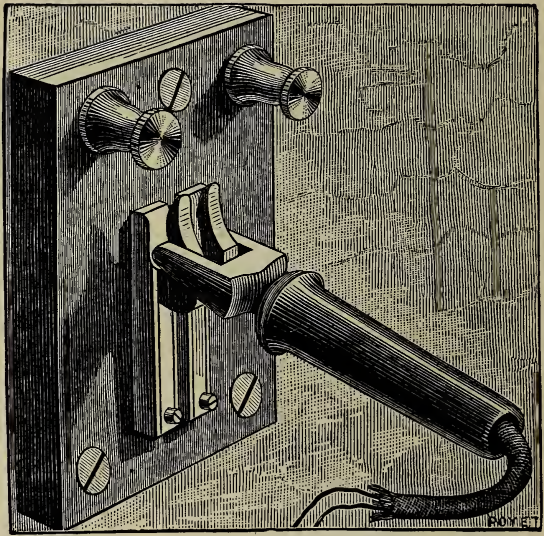
plain and ornamental, and either specially designed for the electric light or both gas and electric light combined, or as in this instance, candles and electric light combined.

In movable fittings it is often convenient to be able to remove the lighting arrangement, or at least the conductors during the day. This necessitates a system by which the separation can be very quickly effected. Fig. 88 shows a very

crude form, but these are being much improved from day to day.

The great Swan lustre which lighted the buffet at the Electrical Exhibition of Paris, in 1881, is historical, and we reproduce it in Fig. 89, but since that time many more elaborate and artistic fittings have been made, but even this shows with what facility the electric light lends itself to decorative effect.

Fig. 88.



In an electric light installation the accessories are very numerous and it is impossible to enumerate and describe them all. Lamp-holders, shades of all colours and designs, multiple-way switches, contact-breakers, fusible safety cut-outs, &c., in endless variety are made by all the suppliers of electric light necessaries, and we would refer our readers to the well-known manufacturers for the latest designs and improvements.

Test Bell for primary and secondary batteries.— When accumulators are used it is often necessary to know the terminals which correspond to the positive and negative poles,

especially during formation, when they are being constantly changed.

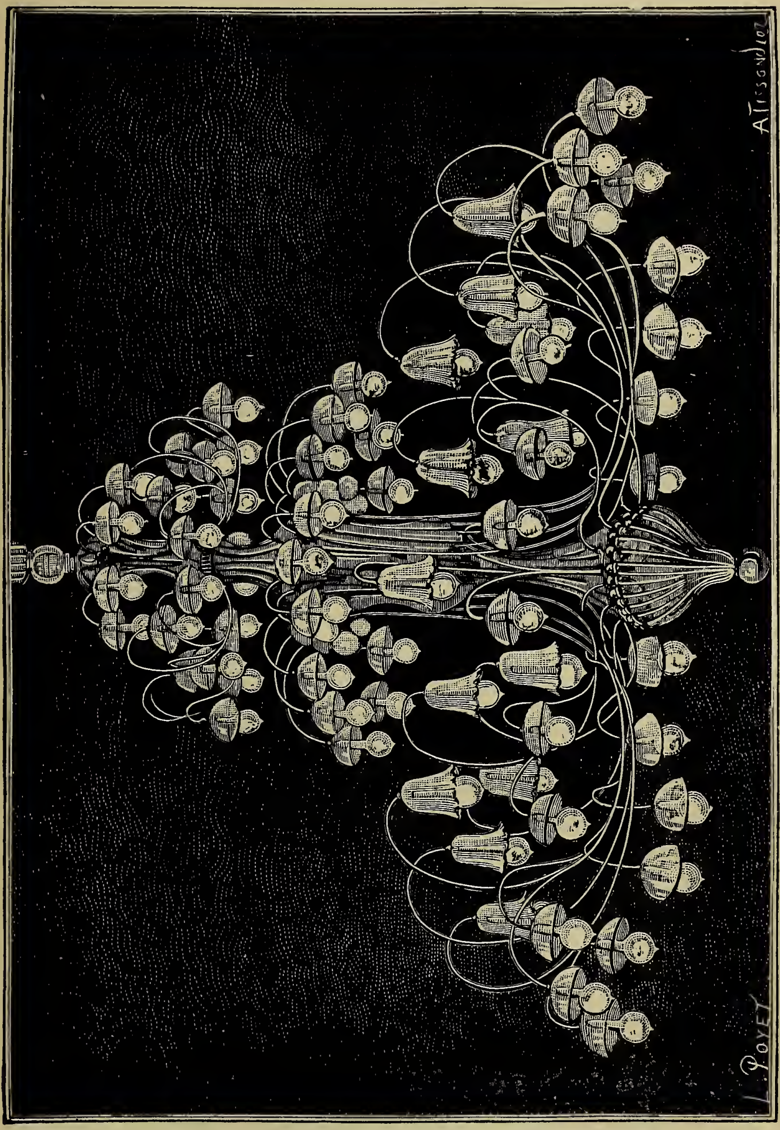
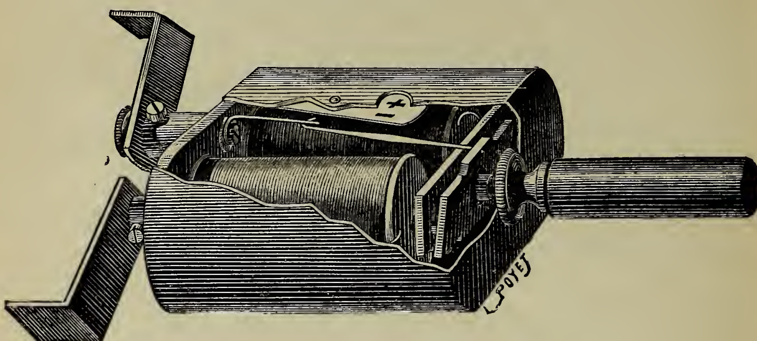


Fig. 89.

The small apparatus shown in Fig. 90, is useful for this purpose. It consists of a small portable bell, in the shape of

a flattened cylinder serving at the same time as a case for the mechanism. A handle fixed to the case enables it to be easily held, and to bring the two movable wing terminals in contact with the two poles of the battery to be tested. The electro-magnet hidden in the case attracts an armature with a small

FIG. 90.



hammer at the end which strikes the bell as will be understood from the drawing. The more or less powerful tingling of the bell indicates with some practice the state of the battery, and the apparatus is a sort of acoustic galvanometer.

This little apparatus may be put in the pocket and enables a great number of elements to be tested in a very little time. A hole in which appears the sign + or —, according to the direction of the current, indicates the name of the pole in contact with the terminal nearest the hole. This result is obtained by means of a small magnetised steel plate, which under the influence of the current passing through the electro-magnet tends to one pole or the other according to which way the current passes.

Switch-board for charging, discharging, and recoupling accumulators.—According to the nature of the charging machine and the apparatus through which the current is discharged, it is often necessary to arrange accumulators in series, multiple arc, or combinations of the two. At other times it may be convenient during formation, for example, to discharge well-formed accumulators through

other accumulators in process of formation. All these arrangements may be effected by means of a mercury commutator of simple construction.

This may be made of a wooden or ebonite board about an inch and a half thick, in which holes are drilled about an inch apart. These holes should be about $\frac{3}{8}$ of an inch in diameter, and about an inch deep. They are nearly filled with mercury.

The first and last rows of holes are joined to terminals by small copper strips, which are sunk into the corresponding holes of these rows. Each series of accumulators is attached by wires to a pair of terminals forming groups 1, 2, 3, 4, &c.

The coupling up is effected by means of movable U-shaped pieces of copper wire of No. 10 or 12 B.W.G., which make contact between the different mercury cells.

These U-shaped wires should be insulated along the part which does not dip in the mercury, so that they may lie over and cross each other without making contact between each other.

Automatic Contact-breaker.—If owing to any cause the source of the charge does not develop an E.M.F. sufficient to overcome the back E.M.F. of the accumulators, they will discharge themselves through the machine, expending in pure loss the electrical energy originally stored.

The object of the automatic contact-breaker is to prevent this by opening the circuit as soon as the charging current is no longer sufficient.

This apparatus consists of an upright electro-magnet, the coils of which are in the charging circuit. This electro-magnet keeps a small armature attracted, and the circuit is closed by a lever plunged into the mercury cells.

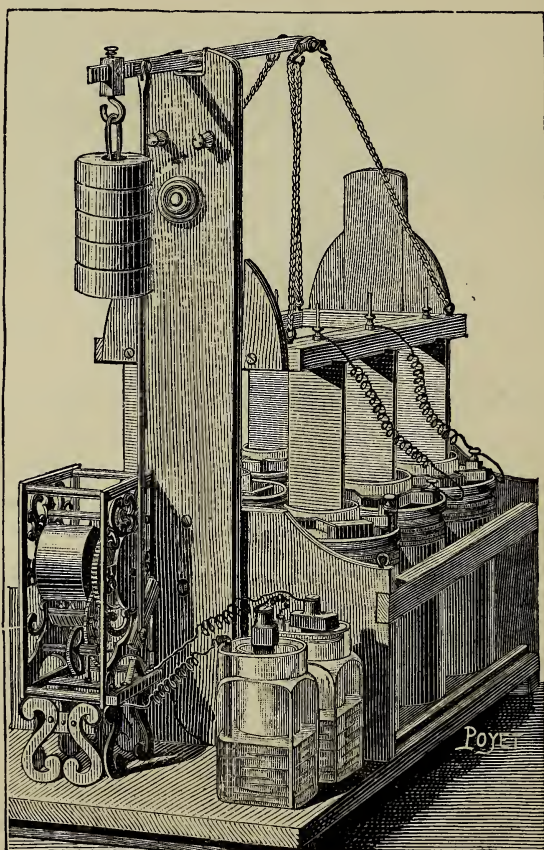
When the current becomes too weak the armature is released, the armature flies back and breaks the circuit before the current has time to reverse. The circuit must then be re-established by replacing the armature by hand.

A more complete arrangement, combining an automatic make and break, itself closes the circuit when the E.M.F. has again become sufficient to effect the charge.

A third mercury cell serves to close the circuit of the accumulator on a bell which gives notice the moment the charging current is broken.

Mareschal's Apparatus to work Bichromate Batteries from a distance. — Bichromate of potash batteries, especially the single fluid batteries, used for domestic

FIG. 91.



electric lighting, have the grave defect of consuming nearly as much zinc on open as on closed circuit, and exhaust themselves uselessly and rapidly if it is neglected to withdraw the zincs from the battery when not in use. But this purely mechanical

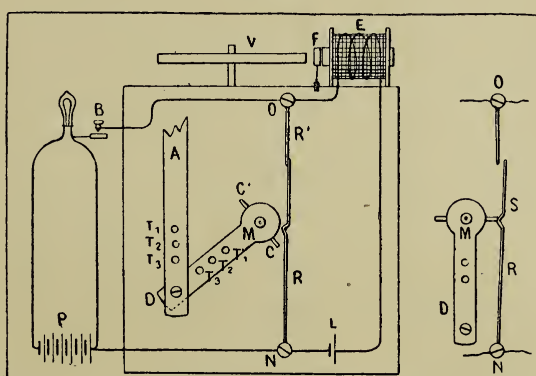
operation necessitates that the battery be placed near to the spot where it is used, or that a complicated and unornamental arrangement of mechanical transmission be put up.

In order to obviate this defect inherent to all bichromate batteries, the arrangement shown in Fig. 91 has been designed.

A frame carrying all the zincs of the battery is suspended from the extremity of a horizontal beam, balanced by means of weights on the other end.

The system thus balanced, the lifting of the zincs or their immersion requires only slight mechanical work, which is obtained from an ordinary clockwork by means of a combination easily understood by reference to Fig. 92, which shows the principle.

FIG. 92.



The axis M moves the crank M D, to which is fixed a connecting rod A, the other end of which is fixed to the horizontal beam supporting the zinc and the counterpoise. If the axis M of the jack be continuously rotated it communicates to the connecting rod a reciprocating motion, which is transmitted to the beam, and alternately immerses the zincs and lifts them out of the liquid.

By stopping the crank M D in suitable positions, the zincs may be maintained at pleasure immersed in the liquid or raised out of it. The clockwork acts on a horizontal fly-wheel V, against which is pressed an iron shoe F, placed opposite an

electro-magnet E. In the ordinary position, this shoe by reason of a spring puts a break on the fly-wheel, but when a current is sent through E, the shoe F is attracted and frees the fly-wheel, the clockwork revolving until the current ceases to pass through the electro-magnet.

The question is therefore reduced to sending a current into the electro-magnet and to stop this current at the proper time. This is easily done by means of an auxiliary Leclanché battery (the battery for the bells of the house may be used), by closing the circuit of this battery on the electro-magnet E by means of a button B, when it is desired to light or extinguish a lamp. In the position of rest, for example, the crank M D is vertical, as shown by the small diagram on the right of Fig. 94. The circuit is opened between M and N by means of the pin C, which keeps the spring R apart from the spring R′. As soon as the circuit is closed, if only for an instant, the crank quits the vertical position, the pin C leaves the bend S, and R, by reason of its elasticity, touches R′ and continues the contact until the handle M D having completed half a turn the pin C′ pushes the plate R and opens the circuit again, the break acts, the crank stops after having revolved through 180 degrees, immersing the zincs to the utmost. To extinguish the lamp the button B is again pressed. The axis M makes another half turn, and when it stops the zincs are entirely lifted out ot the liquid.

The depth of the immersion is regulated by fixing the pin D of the crank in the holes T_1 or T_2 of the connecting rod, which enables the stroke to be varied, and in consequence the degree of immersion.

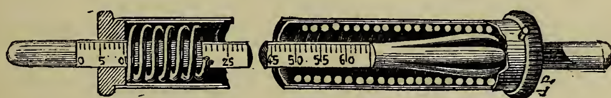
The installation necessitates three wires, two of which join the lamp to the battery, and the third is to work the apparatus by closing the circuit at B.

It is often necessary to vary regularly and gradually the resistance of an electric circuit in order to increase or diminish at pleasure a current which passes through it, particularly in electric lighting by batteries, as in switching on, the first spurt of a bichromate battery before it polarises may be more than the lamps will stand. To obviate this and provide a small

and easily used resistance-coil, Trouvé designed the apparatus shown in Fig. 93.

It consists of a spiral of German silver wire, inclosed in a nickeled brass tube, the spirals being kept from each other and insulated from the brass tube by a pasteboard case. Inside slides an elastic contact, made by a metallic rod split into four parts, slightly opened out from each other.

FIG. 93.



The current comes from the right, passes through the spiral, the contact, and the rod divided in degrees. In the position shown by Fig. 93 the rod is at the bottom, and as the current only goes through one or two turns of the spiral, the resistance introduced is at a minimum; but when the rod is pulled out, the current, before it reaches the contact, must pass through more turns of the spiral, and consequently pass through more resistance. The divisions marked on the graduated rod correspond to the number of turns of the spirals included in the circuit.

This apparatus is applied by Trouvé to his polyscopes; it enables the current supplied by a Planté accumulator to be regulated and to maintain the small platinum wire at the desired degree of incandescence in each particular case.

CHAPTER VIII.

DOMESTIC APPLICATION OF THE ELECTRIC LIGHT.

THIS subject may be divided into two classes, characterised by the presence or absence of a mechanical motor for driving an electrical generating machine: the first applies to large installations for those who are prepared to sink a certain amount of money; the second, small installations comprising a limited number of lamps, and accessible to more modest means.

LARGE INSTALLATIONS.

The arrangements vary with each installation according to the nature of the motor used, the room at disposal, the light demanded, the richness and decoration of the rooms to be lighted, &c.

Fig. 94 shows a complete installation, in a basement, of an Otto gas engine of 4 horse-power driving two Gramme machines for the supply of incandescent lamps distributed over a private mansion.

Lighting Direct.—As an example of this system we may mention the house of M. Porgès, manager of the Edison Company in Paris, who uses a two-cylinder Otto gas engine of 8 horse-power. The machine, Edison K, feeds 60 A lamps requiring each 0·75 ampères and 100 volts at the terminals. The installation consists, however, of more than 100 lamps, because on the one hand all the lamps are never alight at the same moment, and on the other hand a certain number of B lamps are substituted for A lamps, these requiring only 50 volts, and also some lamps of a still smaller type requiring

only 15 volts. The 50 volt lamps B are of course two in series, and the 15 volts seven in series.

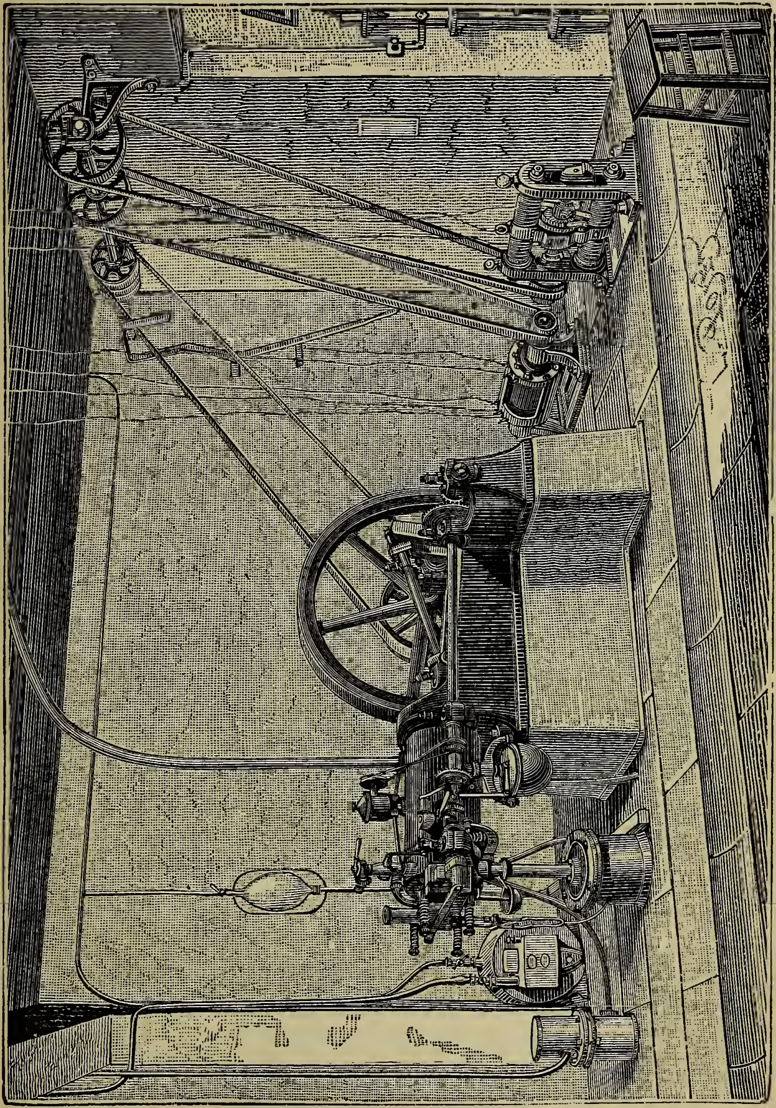


Fig. 94.

The inconvenience of this installation is evident *à priori:* the gas-engine must go, no matter what number of lamps are

alight; but this system works very well in practice, and there are at the present moment hundreds of such domestic installations in this country, many of which have been working for several years and give undoubted satisfaction.

Indirect Lighting by means of Accumulators may in many cases be more advisable, and the following is a sample.

The total installation comprises 150 Swan lamps of 40 volts and 0·7 ampères fed by 22 Faure-Sellon-Volckmar accumulators of the 2 horse-power type all in series.

These accumulators can safely give a current of 40 to 45 ampères which enables 60 lamps to be supplied at once—a sufficient number under ordinary circumstances.

These accumulators are charged daily, during the day, by a shunt machine, the power of which is regulated by means of resistances in the exciting circuit.

This machine is driven by an Otto gas engine of 5 horse-power. With a little experience the servant in charge of the lighting estimates accurately enough the consumption of the previous day in ampère-hours and he recharges the accumulators with about an equal quantity, giving them 10 or 15 per cent. more, to allow for losses and possible errors.

Thus, for example, let us suppose that over night 60 lamps have been alight for 4 hours. The total consumption in ampère-hours will be: $60 \times 0{\cdot}7 \times 4 = 168$ ampère-hours.

The accumulators are recharged for about 5 hours with a current of 40 ampères so as to supply them with $40 \times 5 = 200$ ampère-hours.

Owing to the use of accumulators, the lamps in all parts of the house may be lighted at any time, day or night, by simply turning a switch.

On days when it is desired to light the whole house and so to use nearly all the lamps, the accumulators should be charged thoroughly during the day and then by running the machine parallel with the accumulator nearly the whole of the lamps may be lighted at one time. If the machine gives 60 ampères and the accumulators 40, this makes 100 ampères in all, and quite sufficient for the whole work. The conductors,

thoroughly insulated with indiarubber, should be designed for currents in excess even of this figure, and then even with the maximum current no heating of the leads can take place.

Small Installations.

Direct Lighting.—Easy as it is, and often economical, to install industrial lighting by means of dynamos driven by water, steam, or gas engines, it is difficult and costly to put up a small domestic lighting plant consisting of one or a small number of incandescent lamps to supply each day four to five hours of light. Every one knows that the difficulty consists in the production of the electrical energy, which for small installations should always be obtained through the medium of chemical energy, that is to say, by primary batteries. Unfortunately, comparatively cheap and constant batteries give too weak a current, and it requires a great number of cells to obtain satisfactory results ; constant batteries of suitable output are dear, and have for the most part the defect of expending nearly as much active substances, zinc and liquids, on open as on closed circuit, which necessitates the withdrawal of the zincs from the liquid when the lamps are not lighted. We have previously described (p. 14, 92, *et seq.*) several useful batteries for domestic electric lighting. Their advantages and inconveniences must now be explained.

Lalande and Chaperon's oxide of copper batteries have the great advantage over some others in as much as they may remain set up for several months, without being touched, and that during this time they may supply at regular or irregular intervals, an amount of electrical energy and consequently a corresponding duration of light proportionate to the size of the elements used. Thus during the winter 1883–4 a battery of 12 trough elements of small size supplied light for about 120 hours to a small incandescent lamp of 6 volts. When these batteries are used for direct lighting it is necessary, however, to include in the circuit a variable resistance, which may be gradually switched out as the E.M.F. falls and the internal resistance rises ; besides this, as the batteries become ex-

hausted the E.M.F. and resistance get worse and worse, so that eventually more cells have to be switched in. This of course all means a great loss of energy and the zinc consumed is not in proportion to the useful work obtained from it. Single fluid bichromate of potash batteries may be used for a few hours' lighting. With two windlass batteries of 6 elements each coupled up in tension, 4 or 5 lamps of 14 to 16 volts may be lighted for 4 or 5 hours. We will not go into the photometrical power of the lamps. When it is desired to supply only a single lamp at once the duration of the light may be proportionately increased, but it is necessary not to plunge the zincs too deeply into the liquid so as not to destroy the lamp, as well as in order to diminish the local action which consumes the zinc uselessly.

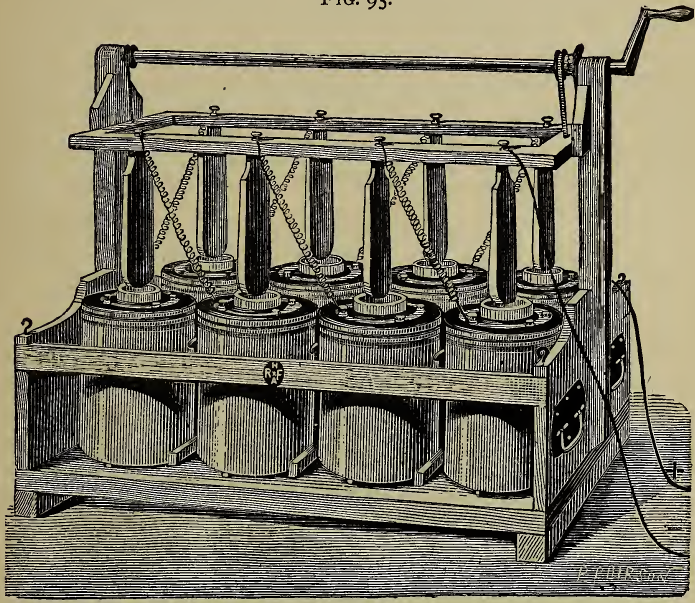
With double fluid bichromate of potash batteries the local action is reduced but the internal resistance of the element is increased by the presence of the porous pot and the output is diminished. With equal dimensions the double fluid batteries can supply less lamps at once than single fluid batteries.

We reproduce here Radiguet's 8-cell battery, Fig. 95, intended to supply one or two lamps of 12 volts. The E.M.F. is about 2 volts per cell, which is 16 volts for the 8 cells in series, and 12 to 13 volts are available at the terminals of the lamp. The disadvantage of this battery is that the acidulated water in the porous pot must be changed every two or three days and the solution of bichromate of potash when it gets a greenish tint, a sign that it is exhausted.

The Daniell cell and its modifications, Callaud, Minotto, &c., are not suitable for direct domestic lighting. The reason is this. It is difficult even when making cells of great size to obtain batteries which at their best have an output of more than one watt (2 ampères and ·5 volt). To supply only two lamps of 1·5 ampères and 12 volts, $1·5 \times 12 \times 2 = 36$ watts are required in the external circuit, which is at least 36 Daniells of large size, cumbersome, costly to buy and to maintain, as they consume on open circuit. Zinc carbon batteries, with acidulated or salt water, have too low an E.M.F. and current. Leclanché batteries, which consume

but little on open circuit, in addition to a small delivery, have the still greater defect of polarising very rapidly on closed current.

Fig. 95.



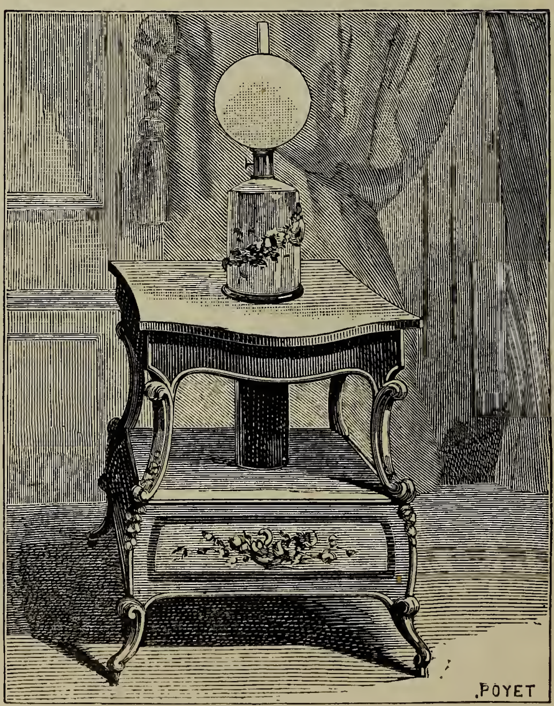
Indirect Lighting.—But although all these batteries are unsatisfactory for lighting the lamps direct, some may be used advantageously in conjunction with accumulators.

Accumulators thus used for domestic lighting act as reservoirs and transformers. As reservoirs they enable a small, but continuous current to be utilised for the production of more powerful effects, intermittent and of less duration. As transformers, by suitably coupling the elements, they enable a greater tension to be obtained than that of the primary current, together with a greater delivery at a proportionate sacrifice of duration. With respect to lighting, this sacrifice is unimportant, as if we assume on an average 4 hours' light per day, this leaves 20 hours per day for charging. It is sufficient therefore if in 20 hours the electric source can supply what we expend afterwards in four, to obtain the light.

The arrangements may be varied indefinitely, but we will content ourselves with describing a few. Fig. 96 shows a small stand with an electric lamp designed by M. Aboilard for stationary or movable lighting. The lamp appears as an ordinary oil-lamp, but the wick is replaced by a small lamp of 6 volts.

The base holds a cylindrical ebonite case of four compartments in which four small accumulators are coupled in tension. The key seen on the left acts on a switch in order to light or extinguish the lamp at will. The four small

Fig. 96.

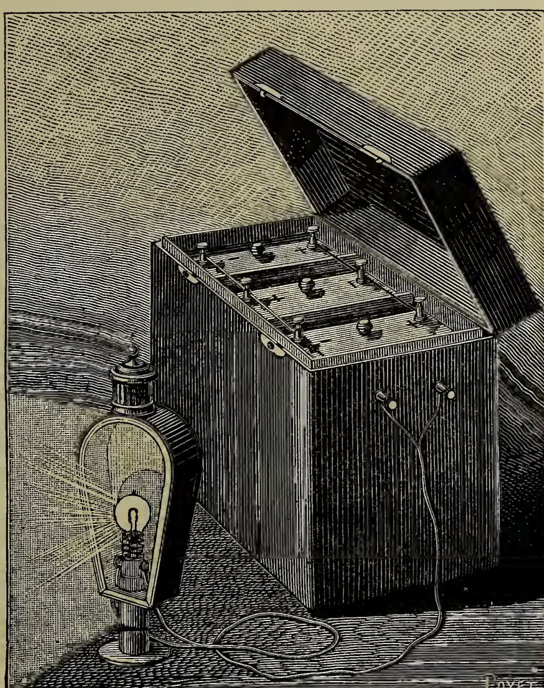


accumulators give light only for a short time owing to their small size, but they are only required when the lamp is displaced. When the lamp is placed on the stand it is in contact with four other accumulators of larger size arranged in a

second ebonite case forming the column in the middle of the table. These accumulators assist the first and together give six hours' light.

The lower compartments of the stand hold the charging battery composed of 16 sulphate of copper elements in series and small enough to go into a space 16 inches square and 9 inches high. These elements are maintained by adding water and sulphate of copper crystals and letting the water, charged by the action of the elements with sulphate of zinc, run out from time to time.

Fig. 97.



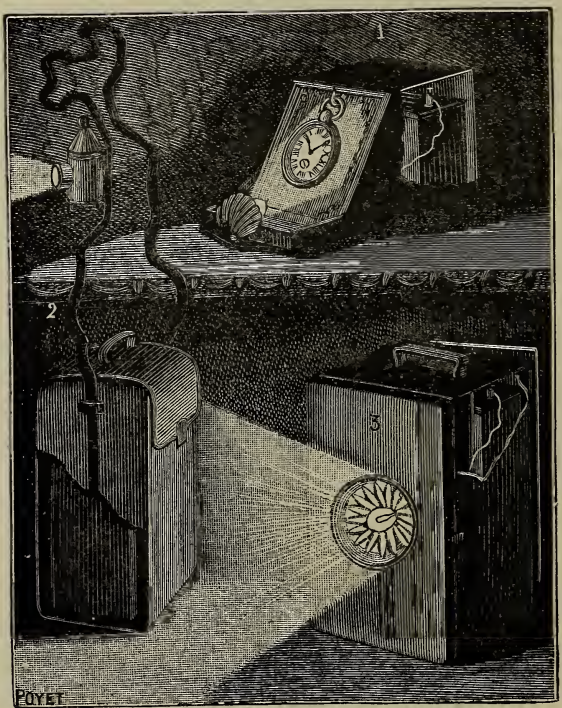
A movable lamp for lighting carriages, which is shown in Fig. 97, has also been used. Owing to a white-metal lining making a reflector, the incandescent lamp fed by three accumulators in series gives a powerful light.

The case holding it is only 9 inches high, and it can easily

be placed under the coachman's seat. When the carriage is put up the accumulators are charged by means of sulphate of copper batteries. Three to four elements must be reckoned for each accumulator.

Fig. 98 represents some elegant and ingenious arrangements, also worked by accumulators of various sizes. No. 1 is a watch-stand very useful at night. It is about $3\frac{1}{2}$ inches

Fig. 98.

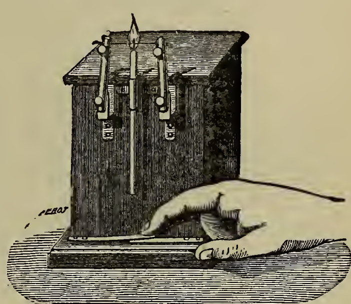


high, $2\frac{1}{2}$ broad, and $7\frac{1}{2}$ long. It holds two small accumulators in series which light a tiny incandescent lamp a quarter of an inch in diameter, placed below the watch in a shell reflector. Awaking at night and wanting to know the time, all that is necessary is to touch the switch on the watch-stand, when the lamp glows and throws the light on the dial of the watch. It not only shows the time, but also lights up the whole room.

No. 2 is a travelling bag carried across the shoulders, holding two accumulators, and weighing two pounds. It lights a small three-candle lamp which may be fixed in the button-hole of the coat. No. 3 is another travelling bag accumulator of greater size, for more extended journeys. Under the heading of Recreations, we will mention electric jewels.

These small lamps may be used for going down into the cellars, seeing the time at night, consulting the thermometer, &c. A small Planté accumulator may also be used to make a platinum wire glow and set light to a candle or stove as shown in Fig. 99.

Fig. 99.



Three small Callaud cells 3 inches high will maintain the accumulator.

In all these applications we have always supposed that the charging battery has a number of elements in tension sufficient to charge the accumulators without changing their coupling.

If this is not the case the accumulators must be coupled up in quantity to charge them, and in tension to discharge them.

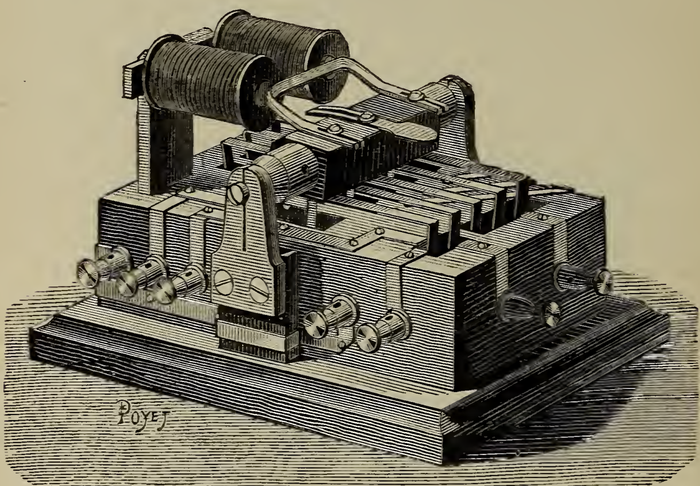
A Planté commutator moved by hand, as described on page 109, may be used, or the Planté-Hospitalier automatic coupler, represented by Fig. 100.

The apparatus is intended without any special manœuvre—beyond switching in or out the lamp or lamps fed by the accumulators—to automatically effect the coupling in quantity to the charging battery and the coupling in tension to the lamps, and to change the accumulators again directly the lamps are put out. It consists of a wooden board carrying a certain number of mercury cups joined to terminals by copper strips; into the cups are plunged jockeys suspended from a horizontal axis turning on pivots.

The apparatus represented in Fig. 100 is arranged for three

accumulators, the terminals being ten in number, viz. two for the charging circuit; two for the external circuit, including the lamp and contact-breaker; three terminals for the

Fig. 100.



positive poles of the three accumulators A, B, C; three terminals for the negative poles of the three accumulators A, B, C.

In the ordinary position, the lamps being out, the plates are in the position as shown in Fig. 100, that is to say, in the charging position; all the positive poles of the accumulators communicate with the positive pole of the charging battery, and all the negative poles of the accumulators with the negative pole of the battery. When the circuit to the lamp is closed the current passes through an electro-magnet having two windings, the one fine and long, the other short and thick. The magnet becoming active attracts an armature which swings the axis carrying the jockeys, plunges them into other cups, and changes the coupling, insulates the charging battery from the circuit, and couples the accumulators in tension.

If the magnet had only one wire, the coupling would be effected as before, but the lamp would not light, the resistance

of the magnet wire weakening the current; but the moment the motion of the magnet is nearly ended the thick wire is shunted into circuit, its resistance being almost nothing; but the magnetism due to the current in the thick coil being powerful enough to maintain the armature in its position, keeps the accumulators coupled in series on the lamps. When the lamp is switched out, no current circulating on the magnet, the jockeys fall back and recouple the accumulators in quantity on the charging battery. The couplings are therefore effected automatically without troubling about a commutator as is necessary with an apparatus worked by hand.

The foregoing relates principally to the uses that have been made of primary batteries and accumulators in France, where the general tendency seems to be in favour of the Trouvé form of single fluid bichromate battery for lighting direct, and the use of constant batteries of low efficiency in conjunction with secondary batteries or accumulators for the indirect mode. In England, however, much greater advances have been made, and the general tendency seems rather to be in favour of modifications of the Bunsen, zinc-carbon, nitric acid battery. Such batteries as the Coad, Emmens, Holmes, Noad, and Ross are well known here, and some of them much used. The Coad battery is a double fluid cell with a bichromate and nitric acid solution, but it does not appear to be any great improvement on other and older forms, and has not been much employed.

The Emmens battery is a really practical thing, and has done good work. The large cell is made of earthenware, with a wooden frame round the top, in which are the terminals, the contacts being made with mercury cups. The outer solution, in which are two zincs, is dilute sulphuric acid, the inner solution, which is kept a secret by the inventor, and called by him "chromozone," is a very efficient depolariser; the porous pot is about 12 by 10 by 2 inches, and is of very porous material, and there are two carbons in each pot. The single-pot cell, with external measurements of 13 by 12 by 5 inches, has an E.M.F. of over two volts, and an internal resistance of 0·02 ohms; it can furnish continuously

in useful work a current of 10 ampères for twenty-four hours, extended over a week if necessary. This battery has been much used for electric lighting, both for public and domestic purposes, and the working cost with Swan lamps of high efficiency comes out about equal to gas at 8*s.* per 1000 cubic feet.

The Holmes battery is made in cells of about the same capacity, and generally in wooden boxes of eight cells. The outer solution is acidulated water, one in fifteen, and the inner solution is nitrate of soda and sulphuric acid. There are two zincs in each cell, and two carbons in each porous pot. The constants are $E = 1 \cdot 85$, $R = 0 \cdot 025$. One 8-cell battery will run sixteen lamps of 10 volts and 1 ampère, or eight lamps of 10 volts and 2 ampères for twelve or thirteen hours, either continuously or extended over three or four days. The porous pots and the outside cells are all connected to a common tube, and by an ingenious siphon arrangement each battery of eight cells can be charged in two operations in about ten minutes. The connections never want touching, except to take out the zincs to amalgamate them, or replace them. With ordinary work they will last from six weeks to two months; that is to say, when an average current of 20 ampères for four hours per day is taken out of them. The working cost with Swan lamps at a high efficiency is about equal to gas at 7*s.* per 1000 cubic feet, and a very great number of installations are now running worked by these batteries, with great satisfaction to the consumer. The efficiency of the battery is very good, about 60 per cent. of the theoretical value of the zinc being obtained in the lamps.

The Noad battery is a carbon and iron battery with nitric acid, but no practical work has yet been done with it.

The Ross battery, like the Holmes, has a very ingenious arrangement for charging all the cells, both inner and outer, at one operation, but although this battery has been much exhibited, we have heard of very little practical work from it.

There are amateurs willing to go to the expense of a small electric lighting installation, seeing the special advantages of

the light, but who are, with reason, afraid of the daily trouble and attention required by most batteries. Give them an installation capable of working properly without undue personal trouble, and numbers of people will adopt the light. In such cases economy is a secondary consideration; but simplicity, easy manipulation, and absolute certainty are paramount.

Domestic electric lighting by means of primary batteries is not, and cannot be, economical, but the cost is not sufficiently high to render it prohibitive.

It suffices to show that it is possible and practicable to tempt the amateur, but we cannot at present expect to see it become general, and our only object is to point out the best known means of obtaining a practical result on a comparatively small scale, and as a luxury.

CHAPTER IX.

ELECTRIC MOTORS.

THE facility with which electrical energy may be transformed into mechanical work, the neatness, elegance, lightness, ease of starting and stopping of electric motors, has seduced many inventors. But, unfortunately, as with lighting, the difficulties met with do not arise from the motor itself, but from the electrical source required to work it.

There are, nevertheless, cases where, for small intermittent purposes, it is convenient to use electric motors fed by batteries direct, or, as previously explained, through the intermediary of accumulators.

These small motors may be very useful in special cases, which we will presently rapidly glance at, but we will commence by briefly explaining the phenomena on which they are based.

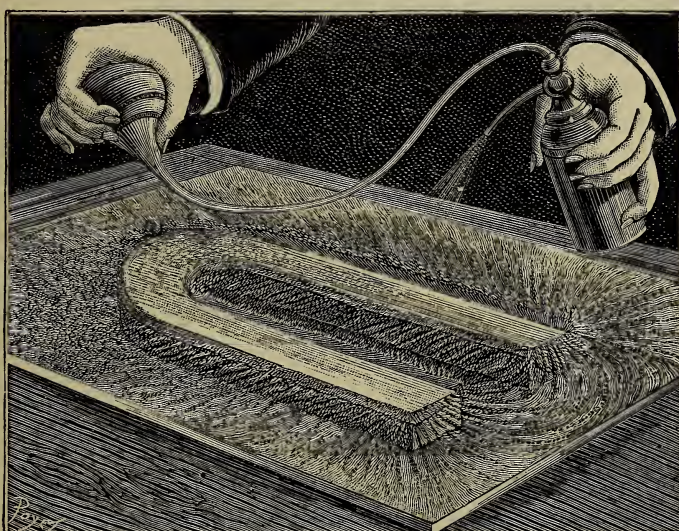
Magnetic Actions of the Electric Current.—Electrical and magnetic phenomena are closely allied to each other, as was first demonstrated by Oersted in 1820, when he showed the action of an electric current on a magnetised needle. A little later Ampère pointed out a rule, named after him, to determine in each case the relative action of a current and of a magnet. This rule itself is nothing more than a consequence of indications furnished by the magnetic figures.

If a thin card or glass plate be placed over a magnet and iron filings are dusted on this plate, it will be seen that the filings take certain positions, and trace certain lines which Faraday called the magnetic "lines of force," the whole being termed a magnetic figure.

[1] The shape of the figure varies with that of the magnet, its relative position to the plate, &c. The whole space under the influence of this magnet constitutes the magnetic field, characterised by the presence of lines of force, the study of which is most important, when considering the laws of electro-magnetic actions, and of induction. It is convenient, in order to study these figures, to fix them, so as to be able to keep them.

Fig. 101 shows how these figures may be fixed. The plate is covered with gum, allowed to dry before being

FIG. 101.



placed over the magnet; the surface is sprinkled with soft iron filings by means of a small sieve, and when the curves are well developed, which will be assisted by gently tapping the plate, a spray of water is gently thrown on its surface, or better still, a jet of steam may be allowed to play on the surface. The gum softens, holds the filings without the particles changing position, and when the gum is dry again, the magnet is withdrawn, the magnetic figure remaining fixed.

Thus a natural representation of the magnetic field produced by the magnet on the glass plate or sheet of paper is obtained. The number of these lines or their density is at every point proportional to the intensity of the field, the curves traced indicate the direction. To complete the definition of the field the direction of these lines of force must be determined. This direction is by definition and convention taken to be the direction in which the north-seeking pole of a magnetised needle displaces itself when free to move in the field. From this definition it follows that the lines of force start out from the north pole of a magnet and re-enter at the south pole, since the north pole of the magnet repels the north pole of the needle, and the south pole of the magnet attracts the north pole of the needle.

Faraday discovered two physical properties of the lines of force, which the magnetic figures clearly prove: (1) The lines of force tend to shorten themselves; (2) two parallel lines of force in the same direction repel each other.

These two actions explain the curved shape which the lines of force take between the two poles of a magnet; they are in equilibrium when their tendency to shorten is compensated by their mutual repulsion.

When a magnetised needle is placed in a magnetic field, by virtue of the tendency of the lines of force to shorten, the needle places itself in the direction of the lines of force of the field, which enter through the south pole of the needle and go out through the north pole. This explains the direction taken by a magnetised needle placed in a magnetic field.

It is by virtue of the same action that an electric current acts on a magnetised needle. In fact, the space which surrounds a conductor traversed by an electric current is equally full of lines of force similar to those produced by a permanent magnet.

In the case of a straight conductor, these lines of force are parallel circles, the centres of which are in the conductor itself and the plane of the circles is at right angles to the conductor. The direction of these lines of force is given by the following rule:—If a conductor be looked at from the end

where the current enters, the direction of the lines of force will be that of the hands of a watch. These lines of force possess the same properties as magnetic lines of force; they differ, however, in an essential point; while magnetic lines of force are always in existence in the field of the magnet without other expenditure of energy than that necessary to originally provoke the magnetism, lines of force due to electric currents begin and end with the currents; they can only exist when a certain quantity of electrical energy is expended in the conductor which they surround.

Principle of Electro-motors.—It will now be easy, if the foregoing has been well understood, to explain the principle of action of an electro-motor.

An electro-motor always comprises three essentials: a permanent or electro-magnet producing the field; a coil, which traversed by a current also produces a field; a commutator or collector to distribute the current in the coil.

Every time a current passes through the coil, its lines of force react on the field. If the bobbin be movable and the field fixed, the former will be displaced to satisfy the mutual attractions and repulsions of the lines of force and tend to take up a position of equilibrium. If at the moment it arrives at this position we reverse the current in the coil by means of the commutator, we reverse the reciprocal action of the field and the bobbin, the attractions change into repulsions, and inversely, the coil tends to take a new position of equilibrium different from the first. When it arrives at this second position we again reverse the current, the directive force again changes, and so on continuously. A series of motions of the coil towards two positions of equilibrium is thus produced, which it cannot retain owing to the successive reversals of the current. Give the coil a suitable shape and arrange it in such a way that the movements to its positions of equilibrium give it a rotation of 180° round the axis which supports it, and we have a rotary motor. The reversals may in this case be very rapid, up to even 200 or 300 times a second. Practically, small motors make at least 1800 revolutions per minute, or 30 revolutions and 60 reversals per second.

In the large size motors the bobbins are divided into sections and the commutator effects the change of direction of the current in the bobbin no longer on the entire wire, but section by section; this is a continuous commutation, the variation taking place only in $\frac{1}{20}$, $\frac{1}{40}$, or even $\frac{1}{60}$ of the coil at once, so that the current remains practically continuous, the dead point is suppressed, the action is more regular, and the efficiency higher.

Small Motors.—The best continuous-current generators are therefore, in principle, the best electro-motors.

But if small forces are to be produced, not exceeding 25 to 30 foot-pounds per second, for example, the problem becomes very different.

The Gramme and Siemens rings become difficult of construction and costly when their dimensions are small. It is somewhat like the difference between a large clock and a small watch. It is therefore necessary to make some sacrifice in the efficiency of the apparatus to produce a simple and cheap motor in order that its use may become general.

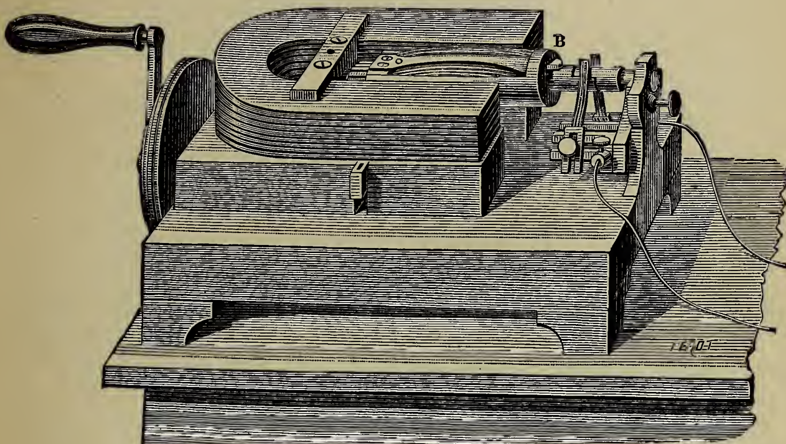
All constructors who have studied this question have returned to the primitive Siemens armature, and we find it more or less modified in most of the small motors at present in use.

The Siemens coil consists of a soft iron cylinder hollowed out by two longitudinal grooves, which gives its section the form of an H. In this groove an insulated wire is wrapped, the ends of which are joined to the two plates of the commutator. The coil thus constructed is placed in a field formed by a permanent or electro-magnet. Under the action of the currents, alternately reversed, which traverse it, it revolves rapidly.

In Deprez's motor, Fig. 102, the field is formed by a horseshoe magnet, and the coil is placed longitudinally between the arms of the magnet, which renders the motor lighter and more compact. The current is brought to the commutator by two brushes of thin brass wire, as in the Gramme machine. The current passing through the coil is changed in direction every half turn. The brushes are fixed to a support turning round the axis of the coil.

The lead of the brushes and the speed of the motor may thus be varied according to the work it has to do. With a magnet weighing about 4 lbs. and an armature weighing about 1 lb., the weight of the complete motor does not reach 9 lbs. At a speed of 3000 revolutions per minute, it develops 184 lbs. per second, with eight flat Bunsen elements.

FIG. 102.



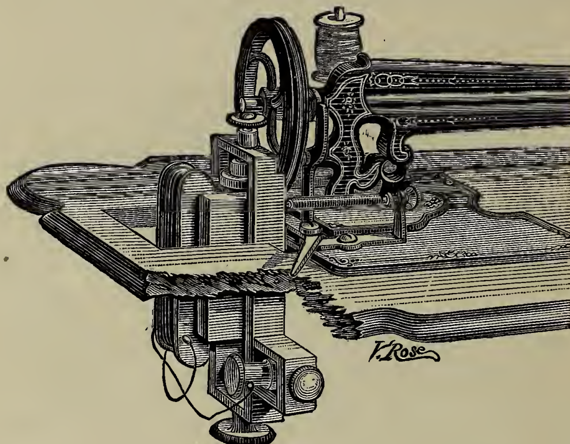
When the speed becomes too great, a small spring, in fixed communication at one end with one of the ends of the coil, and pressing by its other end on one of the commutator plates, flies back, by the effect of the centrifugal force. The circuit is broken and remains open until the speed becomes normal. Practically the breaking and making of the circuit takes place quickly enough to prevent the speed varying from the normal by $\frac{1}{700}$.

Trouvé's motor also consists of a Siemens armature with poles slightly excentric, turning between the arms of an electro-magnet in series with the armature.

Fig. 103 represents Trouvé's motor applied to an ordinary sewing machine. The motor is fixed vertically. The shaft carries a pulley with a rubber tyre which presses against the fly-wheel of the machine and thus communicates the motion. The difference between the diameters being great

the motor may run at a great speed, which warrants its small dimensions. The pressure of the pulley on the fly-wheel is regulated by means of a spring. It is easy to disconnect the sewing machine from the motor by moving a lever which

FIG. 103.

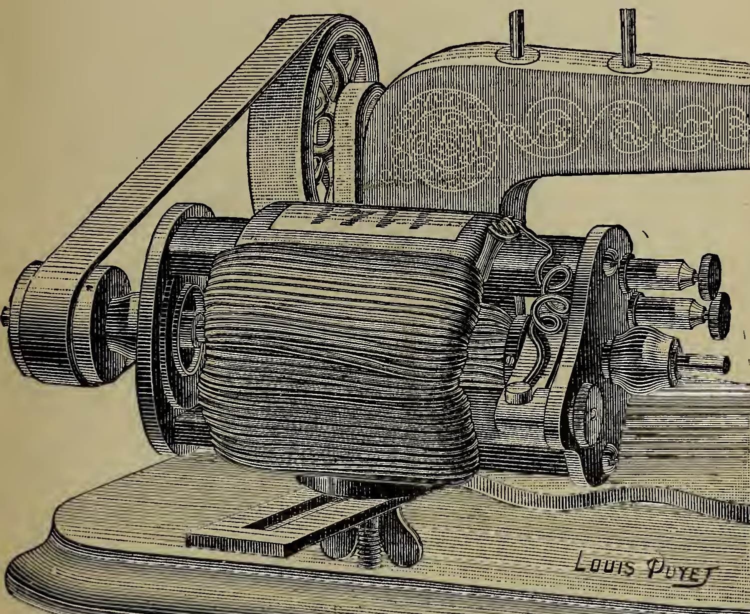


moves the motor pulley away from the fly-wheel. The band is then replaced and the machine can be worked by the treadle, which is very convenient if accumulators are used, which, by negligence or any other cause, may be exhausted. Stopping and starting the machine is very simple. By pressing the pedal two actions are produced: the first sends the current into the apparatus, the second causes a graduated strain on a chain composed of a number of silver links introduced in the circuit. More or less strain exercised on the chain reduces or increases the resistance. This application of microphonic contacts is due to Reynier, and provides a simple arrangement to regulate instantaneously and at will the speed of the machine.

The Griscom motor, Fig. 104, for small work, is about 4 inches long and weighs under 3 lbs. Nevertheless, at a speed of 5000 revolutions per minute, it can give out 20 to 25 foot-pounds per second. The Siemens H armature is used, and revolves in a magnetic field formed by a ring-shaped

magnet with consequent poles. The armature is entirely inclosed by the field-magnet which protects it. The armature and field-magnet are of malleable castings, the coercive force of which is as low as that of soft iron. Thus all the parts may be cast, making their manufacture very cheap.

FIG. 104.



The apparatus is easily applied to any existing sewing machine ; a small slotted support and a wing-nut on the lower part of the motor are all that are required.

With this motor a bichromate of potash battery of six elements is generally supplied.

The speed of the motor is regulated by plunging more or less of the electrodes into the liquid by means of a pedal placed on the side of the case containing the cells ; a single charge of the battery is said to be sufficient to do 500 to 1000 yards of sewing, either in a fortnight or in six months at irregular intervals. This is a veritable domestic application,

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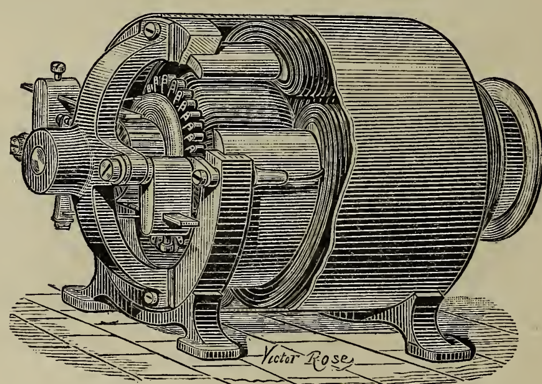
if the inevitable recharging of the battery be attended to when it has supplied the work it is capable of producing.

When power exceeding 25 to 30 foot-pounds per second is required, continuous-current machines are more regular, lighter, and cheaper motors than those of total reversion of the current, founded on the principle of the Siemens H armature.

To obtain a solid, light, and compact motor, Gramme has modified his dynamo machine to the cylindrical motor represented in Fig. 105. Its essential parts of course are as

Fig. 105.



usual the field-magnets, the ring armature, and the commutator, but the whole is neatly arranged and well-protected by a covering of sheet brass ; Fig. 105 shows a part of this brass covering cut away, enabling the internal arrangements to be seen. They may be made in all sizes from 10 foot-pounds per second to 2 or 3 horse-power.

Ayrton and Perry's Motor.—Owing to theoretical considerations which we cannot go into here, Professors Ayrton and Perry have shown that dynamos should not have the same proportions existing between their different parts, when intended to act as generators as when intended for motors.

A generating dynamo should have massive inductors or

field-magnets, so as to form an intense magnetic field, while in a dynamo machine acting as motor it is preferable to have a very large armature and a small field-magnet. It is therefore necessary to reverse the usual order of things, and make a motor as shown in Figs. 106 and 107, which may be defined

FIG. 106

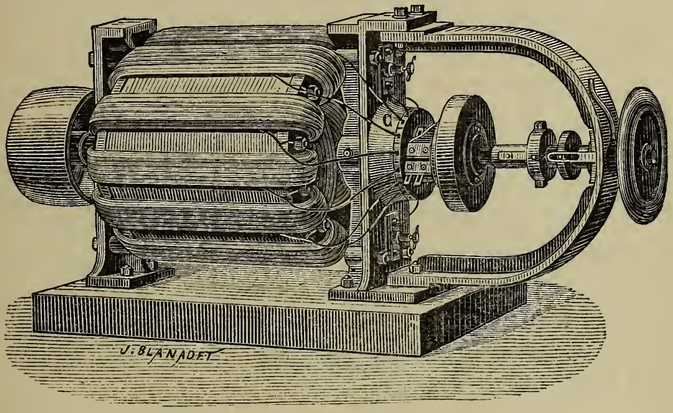
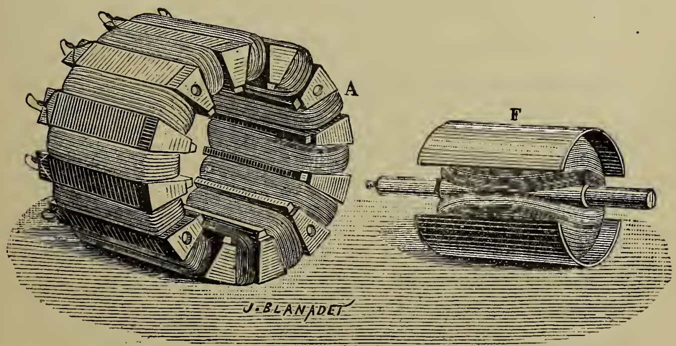


FIG. 107.



as a reversed Pacinotti-Gramme machine with movable field-magnet and fixed armature. The field-magnet, represented separately at F, Fig. 107, is nothing else than a Siemens H armature, revolving inside a Pacinotti ring, represented by A; the different sections of this ring are

joined to a fixed collector, flat or circular; the field-magnet in revolving moves with it two brushes which press on the collector and make the commutation. In motors intended to be controlled by hand, boat motors, domestic motors, &c., the speed is regulated and the direction of rotation is changed by altering the lead of the brushes by means of a lever.

The smallest type of Ayrton and Perry motor weighs about 34 lbs., and is constructed to supply an average work of $\frac{3}{10}$ horse-power, that is to say, about 160 foot-pounds per second. These motors, according to the E.M.F. and current at disposal, are made of three types, requiring 25, 50, or 100 volts at the terminals to act normally.

25 *Volt Type.*—At 1800 revolutions per minute, it produces 0·3 horse-power, with 22·4 volts at the terminals, and a current of 25 ampères. The efficiency, that is to say, the proportion between the mechanical work available on the motor shaft measured by brake, to the electrical energy between the terminals, is 39 per cent.

50 *Volt Type.*—At 2000 revolutions per minute, it produces 0·33 horse-power, with 48 volts at the terminals, and a current of 14·2 ampères. The efficiency is 36 per cent.

100 *Volt Type.*—At 2100 revolutions per minute, it produces 0·35 horse-power, with 98 volts at the terminals, and a current of 6·1 ampères. The efficiency is 38 per cent.

From these figures it will be seen that the efficiency of small motors is very low; in fact, it is necessary that the work produced reach one horse-power for the motor to transform into work 50 per cent. of the electrical energy absorbed. To give an efficiency of 60 to 70 per cent. it is necessary that the motor produce at least three or four horse-power.

The figures which we have given enable the number of primary or secondary cells necessary to work one of these motors at its normal speed to be readily ascertained.

It is necessary to know what difference of potential is available at the terminals of the element at disposal when it is made to deliver the number of ampères required by the motor. This difference of potential available at the terminals

must not be confounded with the E.M.F. of the cell ; it is always less, and may even be only half the E.M.F.

Let us assume, for example, that we have an accumulator capable of delivering 15 ampères, with a difference of potential available at the terminals of 1·5 volts.

This accumulator may work the 50 volt type, requiring only 14·2 ampères. The number of cells in series required will be

$$\frac{50}{1 \cdot 5} = 33 \cdot 3.$$

Therefore, 34 cells in series must be used. If, on the contrary, we use accumulators of larger dimensions, capable of supplying 25 ampères, with the same useful difference of potential, 1·5 volts, the 25-volt type of motor may be used. The number of accumulators to be coupled in series will be found to be reduced to

$$\frac{22 \cdot 4}{1 \cdot 5} = 15.$$

If, on the other hand, batteries incapable of delivering more than 6·1 ampères are only available, the 100-volt motor must be chosen, and the number of elements in series must not be less than

$$\frac{98}{1 \cdot 5} = 65 \cdot 3 \text{ elements.}$$

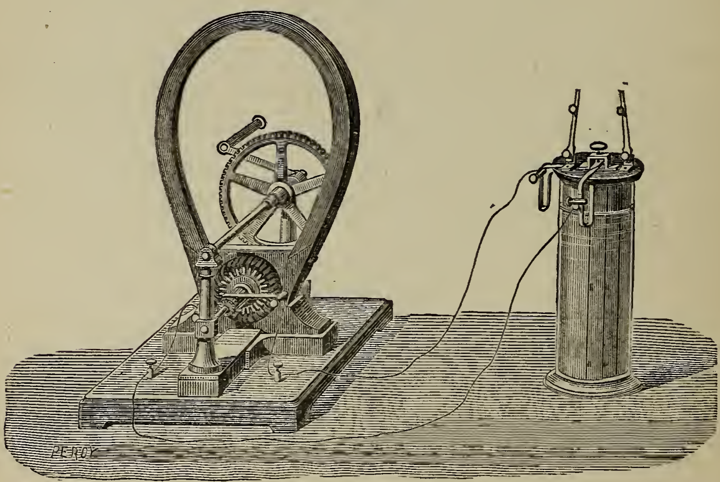
The number of elements varies inversely as the current, but it will be seen that the product of the current into the number of elements is constant, as is also the work itself, which is in conformity with the principle of the conservation of energy.

Reversibility of Dynamo-Electric Machines.—Every mechanical generator of electrical energy may be used as a motor, and *vice versâ*, by virtue of the principle of reversibility. Thus, a most instructive and interesting experiment may be made by means of a hand Gramme machine and a Planté accumulator (Fig. 108). The machine when driven by hand, expends mechanical energy, and produces electrical energy which is stored in the accumulator in the form of

chemical energy by reducing one of the lead plates and peroxidising the other.

If the charging current is then stopped, and the plates left closed on the circuit of the machine, the substances previously separated combine, producing electrical energy, which passing through the machine, produces mechanical energy by putting it in motion. This is one of the most beautiful

FIG. 108.



demonstrations of the unity of physical forces and their mutual transformations. The practical consequence is that one and the same machine may act alternately as generator and motor, according as it is supplied with power or electricity —a most important consequence from the practical point of view.

CHAPTER X.

ELECTRICAL LOCOMOTION.

ALTHOUGH electrical locomotion has so far not been absolutely perfected, many attempts, some crowned with success and capable of practical application in special cases, prove that the actual realisation is not far distant. Each improvement in batteries or accumulators, every perfection given to small motors by decreasing their weight for a given power, and increasing their efficiency, are steps in advance. It is, therefore, not without interest to review the results obtained up to date, if only to show what has been accomplished and what has still to be attained.

We shall not refer here to aerial locomotion, although this subject has within the last month or two made wonderful advances; a balloon fitted with a propeller driven by batteries and an electro-motor, having actually ascended under perfect command and having made a trip of several miles, was brought back to the starting point. This subject is, however, hardly within the scope of the present work, and we shall confine ourselves to land and water locomotion.

LAND LOCOMOTION.

The dream of amateur electricians is to possess a vehicle driven by electricity. What is more charming than to have one at disposal, started and stopped instantaneously by simply turning a switch without further trouble?

Unfortunately the cup is still far from the lip, and this dream of all, has up to the present not been practically realised. The principal difficulty always is, as with lighting,

and as with small fixed motors, the difficulty of producing easily and conveniently the necessary electrical energy. But here the difficulty is increased by the fact of the mode of employment itself; the vehicle must carry the source with it; it must, therefore, at the same time be powerful and light in order not to expend all the work which it produces in drawing its own weight and leave nothing available for useful work, that is to say to move the weight of the travellers. The struggle between batteries and accumulators is eager, and it is still difficult to give an opinion. Both have their advantages and inconveniences.

Accumulators are in existence, which can supply a horse-power-hour of electrical energy per 80 lbs. of weight, but Messrs. Renard and Krebs have, it appears, recently combined an exceedingly light battery which is kept secret, capable of giving this horsepower-hour from a weight of less than 40 lbs. Accumulators may be recharged by a machine, which is an advantage and a saving when the motive power is available and a disadvantage in the contrary case. On the other hand, batteries are very costly and require so much attention every time they are to be used.

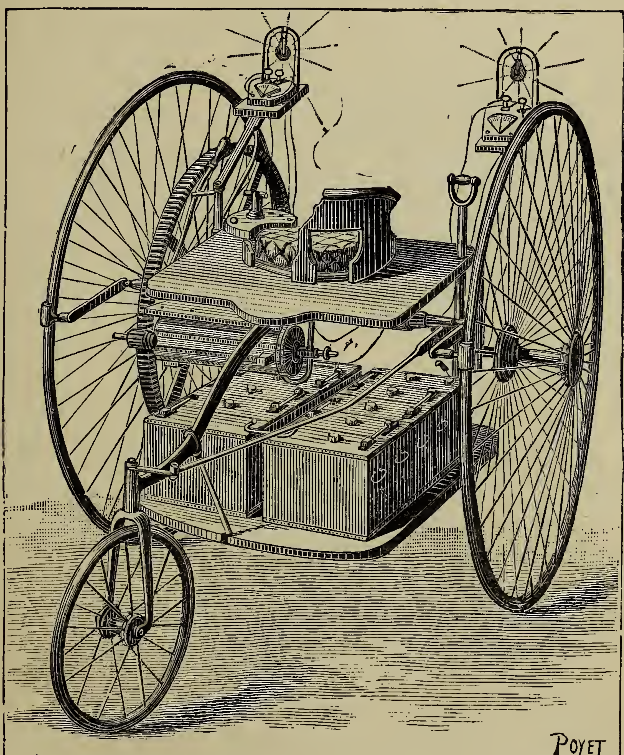
Perhaps, after all, batteries might be made serviceable for the purpose if we could feed them *en route* as locomotives are fed with water. What renders batteries so heavy is the enormous quantity of solution which must be carried to insure prolonged action. Water in this case is ballast, and a very inconvenient ballast. Instead of carrying the whole of the solution all the way, if we could so arrange that we only carry a part and then obtain fresh *en route* as required, in the same way as a locomotive engine is watered, it would be a great advance. We should then require on the vehicle only the supply of zinc and active material necessary for the whole journey. Two kinds of batteries may be arranged for use in this way. One is a zinc carbon battery with a solution of chromic salt, which may be dissolved as required, letting the exhausted liquor run off from time to time.

The second battery is a kind of zinc and peroxide of lead accumulator, in which the space required for the liquid is

very limited; the latter may be supplied as required and the solution which, after use, is composed almost exclusively of sulphate of zinc, may be thrown away. During prolonged stoppages the battery may be left dry, and thus local action on the zincs is avoided.

This combination, complicated as it may appear, has its advantages: the E.M.F. will be very high, 2·35 volts, and constant as long as the peroxide of lead plates are not exhausted, and then they may be replaced. The equivalent of

FIG. 109.



zinc being less than that of lead, the negative plates may be lighter in the proportion of one to three for the same quantity of electricity. Finally, the renewal of the liquid enables the

positive plate to be more completely exhausted, and to obtain for a given weight a greater quantity of electricity and to increase in fact the storage capacity.

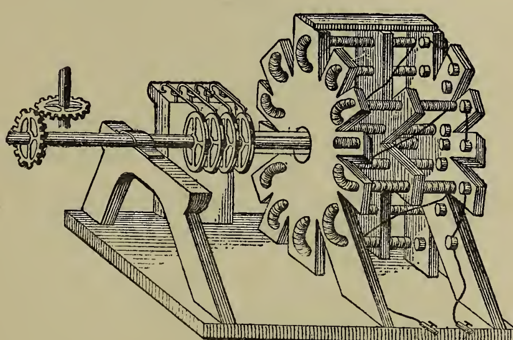
As regards what has been already done in the direction of electric locomotion by land, we shall not refer to the electric rail and tramways in existence, as this hardly comes within the province of amateurs, but for them the electric tricycle represented in Fig. 109 will have more interest. This was used in London in 1882 by Professor Ayrton. The energy is furnished by ten Faure-Sellon-Volckmar accumulators of a special type, placed under the seat. These accumulators work an Ayrton and Perry electro-motor weighing 40 lbs., and giving an effective work of 180 foot-pounds per second. This motor drives one of the large wheels of the tricycle by means of a pinion and cogged wheel on the axle of this wheel. The rider has to his hand a commutator enabling him at will to vary the number of accumulators in circuit according to the nature of the ground and the speed required, also the break and the steering gear. An am-meter and a volt-meter indicate at any moment the electrical energy being expended. Finally two Swan lamps act as side lights and illuminate the measuring instruments. The result probably was not very successful as, so far as we know, no other apparatus of this type has been constructed since. But from this it must not be concluded that the idea of small electric vehicles is abandoned. Their study is being followed up by many people, and there is no doubt that when this application becomes more perfect and practical, very numerous purchasers will be forthcoming.

Electric Navigation.

The idea of applying electricity to the propulsion of boats is far from new. The invention of the electro-magnet demonstrated the possibility of producing mechanical work by means of an electric current. It was not difficult for electricians fifty years ago to use the power of an electro-magnet to work small electro-magnetic engines. The first attempts of Jacobi,

Davidson, Henry, Ritchie, and Page, produced a number of electro-motors which only required a cheap source of electricity to find many useful applications. No great effort of invention was necessary to understand that if a sufficiently powerful battery could be placed in a boat, it would be possible to work a motor which would effect the propulsion of this vessel. This idea, one of the first amongst the numerous applications of the electro-magnet, was first realised by Professor Jacobi of St. Petersburg, who in 1838 constructed an electric boat. Fig. 110 represents the primitive electro-motor devised by Jacobi to propel his boat. Two series of

FIG. 110.



horseshoe electro-magnets were fixed to solid wooden frames; between the poles of these electro-magnets revolved a sort of wooden star carrying a number of straight electro-magnets.

By means of a revolving commutator, consisting of a series of toothed wheels, the current was changed in direction at regular intervals, the movable electro-magnets being first attracted, then repelled, thus producing a continuous rotary motion.

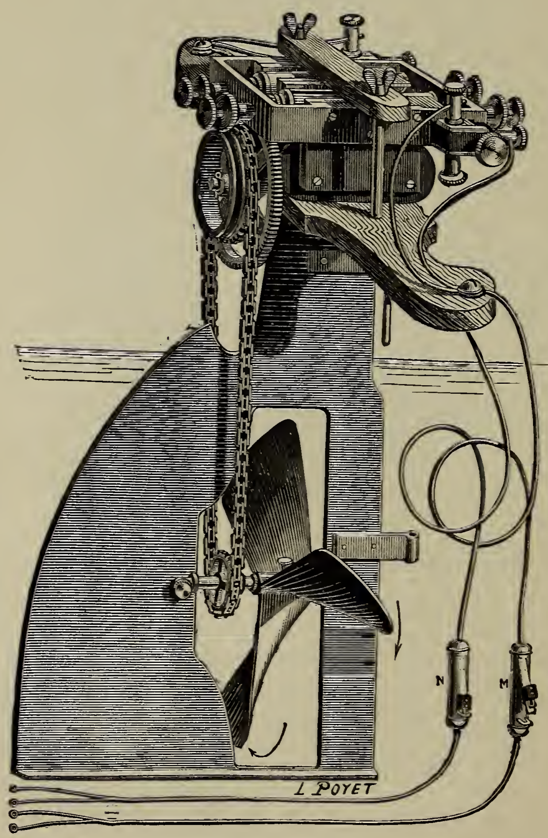
This magnetic engine was at first worked by a Daniell battery of 320 cells of zinc and copper plates, each having a surface of 36 square inches, excited by a solution of sulphuric acid and sulphate of copper. This battery only gave a maximum speed of 1¼ mile per hour.

In the following year, 1839, the Daniell cells were replaced

by 64 Grove elements, the platinum plates of which had 36 square inches of surface. The boat, 28 feet long, $7\frac{1}{2}$ broad, and drawing 3 feet of water, was run on the Neva carrying fourteen persons at a rate of $2\frac{1}{4}$ miles per hour.

Trouvé's Boat.—Trouvé had the ingenious idea, in order to render electric pleasure boating convenient and

FIG. 111.



practical without essentially altering the hull of the boat, to place the motor on the top of the rudder and to communicate the motion to the screw by means of an endless chain, Fig. 111. The battery consisted of two bichromate of potash

windlass batteries of six elements each, which we have previously described. These batteries take up a limited space, and may be easily put on board a boat. The current is conveyed to the motor by the two yoke lines, which are of flexible wire, and contain also a switch to open and close the circuit at will. The boat may therefore easily be steered at will, and the speed regulated. The screw moving with the rudder, of which it is part, gives the boat a list when the rudder is hard over, and then the boat may be turned almost in her own length.

The first boat thus fitted was tried on the Seine, near the Pont Royal, on the 26th May, 1881. Fig. 112 represents this experiment, in which a speed of about 2 miles per hour against stream, and 5 miles with stream was reached.

Electric Boat with Accumulators.—The great quantity of electrical energy which it is possible to store in accumulators, and the power of expending this energy quickly or slowly at will, gave the idea of using these remarkable properties in pleasure boats. The first electric boat with accumulators was constructed by Mr. A. Reckenzaun, engineer of the Electrical Power Storage Company, of London, and tried on the Thames on the 28th September, 1882. Fig. 113 shows the boat under weigh; Figs. 114 and 115 are sections showing the principal arrangements.

The launch *Electricity* is built entirely of iron, its length is nearly the same as the wooden boat of Jacobi. It holds twelve persons; the screw makes 350 revolutions per minute, and the motor working it, 950. The accumulators, 45 in number, weigh rather over 2 tons, and will give 4 horse-power for 6 hours.

They are of the Faure-Sellon-Volckmar type, of a specially compact manufacture for launch work; each element contains 40 plates and weighs nearly 40 pounds. They are 10 inches in depth and 8 inches high. There is room in the boat for 54 elements of this type, but only 45 were carried on the trial trip. These accumulators will supply more than 30 ampères for 9 hours, which corresponds for the 45 accumulators to a total electrical energy—external and internal—of 36 horse-

power-hours, of which it is possible to obtain usefully 20 to 24 or about 4 horse-power for 6 hours.

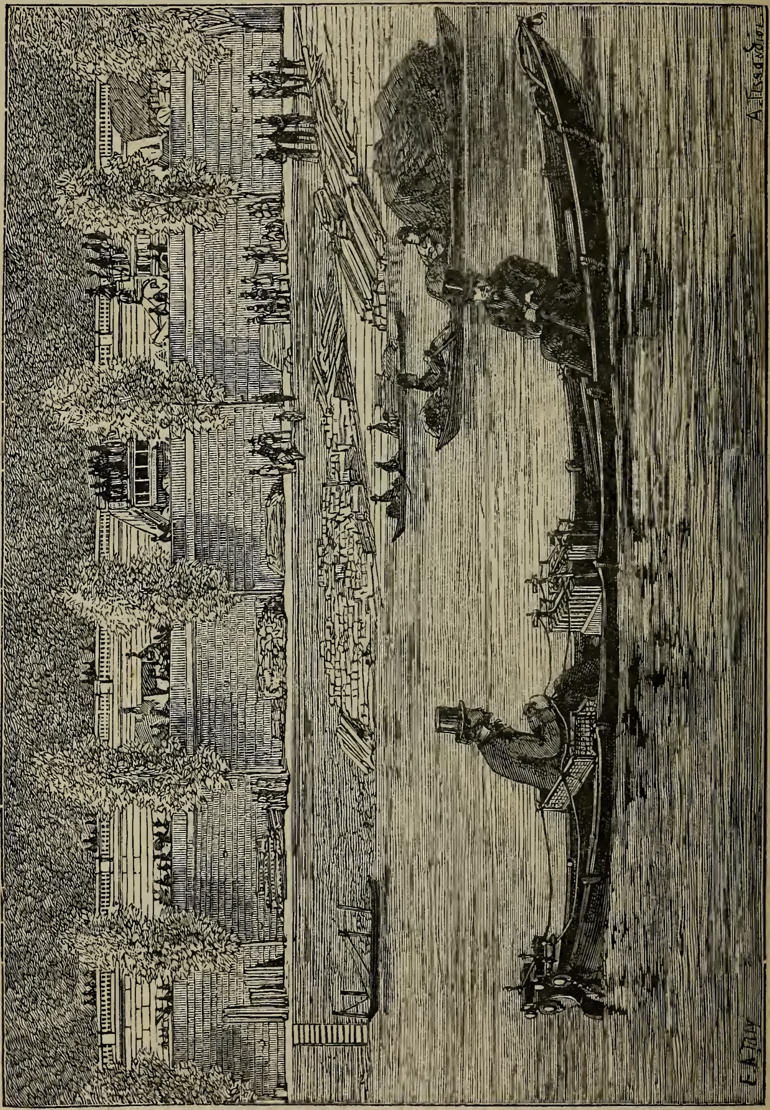


FIG. 112.

These accumulators work two dynamos of the Siemens D^3 type furnished with reversing gear and regulators, so as to

run the screw at will in either direction, and at any speed. Either or both of these motors may be switched into circuit

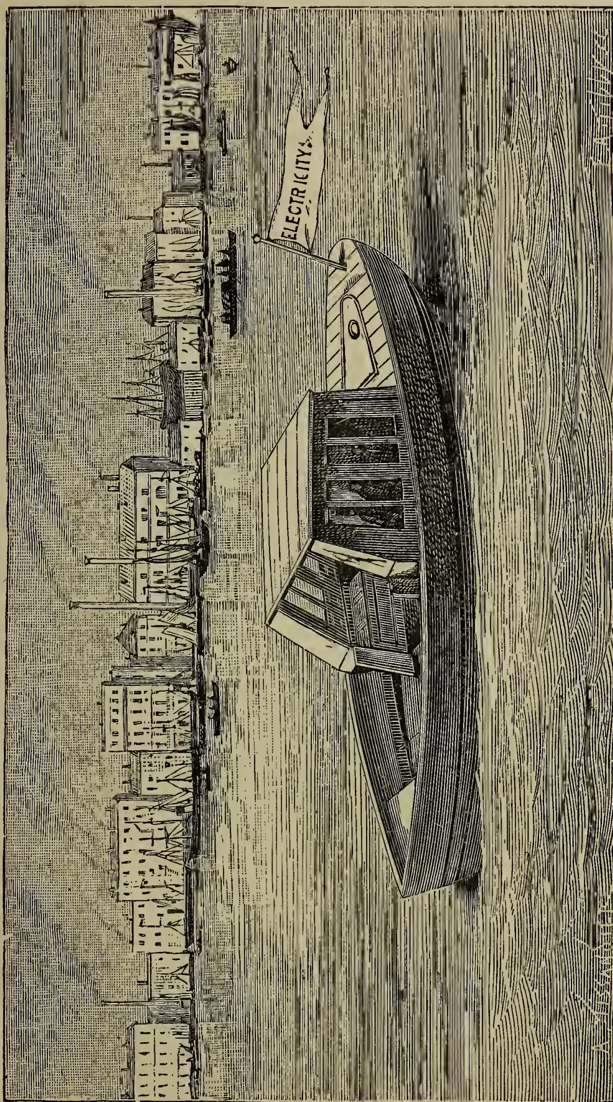


Fig. 113.

at a time. On the first trip a speed of 8 miles per hour was attained against the tide, in presence of a long line of

spectators massed on London Bridge, who watched this boat, which, without steam or visible power, and even without a visible helmsman, made its way against wind and tide. The total E.M.F. of the accumulators was 96 volts, and during the journey the current was maintained very steady at 24 ampères in each machine. Calculation shows that this corresponds with an expenditure of electrical energy of 3·1 horse-power.

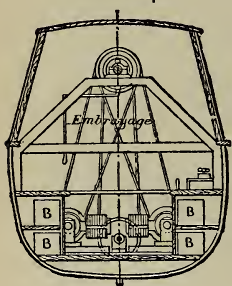


Fig. 114.

The two Siemens machines work by belts on to a counter-shaft above, fitted with friction gear, enabling them to be connected or disconnected at will.

A third belt works the screw-shaft. Each of the dynamos is provided with two pairs of brushes arranged opposite the collector, one pair for going ahead, the other for going astern.

The accumulators arranged underneath the seats make a perfect ballast, and leave the deck entirely free. It results, therefrom, that a 36-foot electric launch is, as regards the number of passengers that may be carried, and their convenience, equal to a steam launch 50 to 60 feet long; all the parts are accessible, and the launch is entirely free from smoke, steam, cinders, and noise.

Considered from the point of view of comfort, the electric launch is thus evidently perfection; the cost and maintenance is more than that of a steam launch, but it must not be forgotten that expense is often in these cases a secondary consideration.

For the application to become general on a river, it will be necessary to erect charging stations where electricity may be taken in, in the same way as at present coal is taken in.

In short, when the accumulators have been charged, they keep their charge a long time, while the loss does not exceed 1 per cent. per day; they represent, therefore, an amount of electricity always ready at a moment's notice, while it is impossible to start a steam launch under two or three hours' notice. Perhaps a system may even be invented whereby the

recharging of the accumulators may be effected free of cost during long stoppages, either by using the wind or even by using the stream of the river by means of floating wheels.

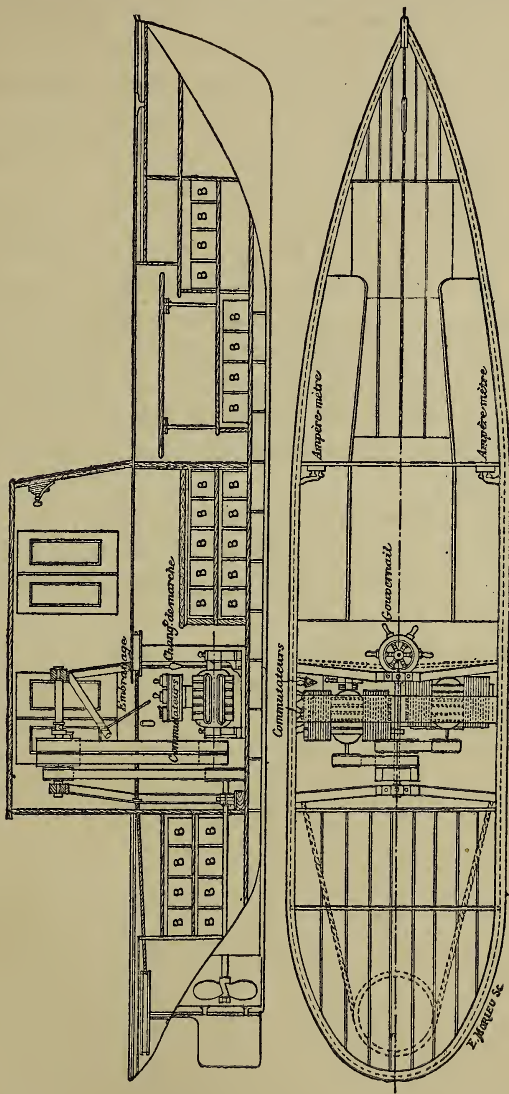


Fig. 115.

While we are speaking of new ideas, let us mention another. Could not the great speed of electro-motors be

used to supplant the screw by a hydraulic propeller worked by a rotary pump? The attempts made in this direction have, if our information is correct, given encouraging results. Would it not do to resume these trials with electro-motors, the speed of which is particularly favourable to this application? The suppression of the screw would have considerable advantages, especially where the draught of water is small and where the impurities of the water, weeds, floating matter, &c., expose the screw to continual danger.

As a matter of fact, electric navigation, like land locomotion, is still of small account when bichromate batteries are used, or a great luxury with accumulators, but certainly a great future may be predicted for it, when it is considered that the experiments are of so recent a date, and taking into account the surprises and progress that the future may have in store. Awaiting the arrival of the electric launch as an every-day thing, let us record their entry into the nautical sporting world.

A race between two electric launches, the *Electricity*, which we have described, and the *Australia*, of a more recent construction, and fitted with more perfect apparatus, has lately taken place on the Thames.

As might be expected, the new boat won. When shall we have "electro-cycle" races?

CHAPTER XI.

ELECTROTYPING, PLATING, AND GILDING.

THE discovery of the art of metallic deposition by means of a current is well known, and we will content ourselves with rapidly glancing at the more simple processes whereby the amateur may obtain interesting results, either in the reproduction of medals and metallisation of small objects, or by fine and adherent deposits of gold, silver, and nickel.

Electrotyping is the art of effecting a non-adherent metallic deposit, thick enough that the metal deposited may itself form a fresh object, and be capable of a separate existence apart from the original mould, preserving its configuration and dimensions.

The phenomenon of electro-chemical deposition is based on an electrolytic action of the current, the principle of which is the following: let us suppose, for the sake of example, that we have a vat filled with a saturated solution of sulphate of copper, in which two copper plates are plunged; join these two copper plates to the two poles of a Daniell cell; the passage of the current will effect the decomposition or electrolyse the solution or electrolyte. The metal, which here is copper, will be deposited on the plate fixed to the negative pole of the battery or cathode, while the sulphuric acid, freed by the decomposition, attacks the plate fixed to the positive plate of the battery or anode, and dissolves it. If the action is very regular, and the anode very pure, the weight of copper deposited on the cathode will be equal to the weight of copper dissolved from the anode, and will itself be proportional to the quantity of electricity which has passed through the

circuit. To obtain a good and regular deposit, called by Smee "reguline," certain relations between the composition of the bath, the current, and the surfaces to be covered must exist, and this we will presently more fully explain.

If we replace the copper plate by a suitable mould rendered conducting, the electro-chemical deposition will take place on this mould, and when the piece is separated from the mould, it will be found to reproduce in hollows all its reliefs, and *vice versâ*.

We will now describe the moulds, the baths, and their general management.

Moulds.—The substance originally used was plaster of Paris, but as it is porous, it must be made impermeable. At present moulds are made in stearine, wax, marine glue, gelatine, indiarubber, and fusible alloys. When the moulds are hollow, a metallic skeleton of platinum is arranged internally, joined to the anode, which serves to distribute the current, and to equalise the deposition; these wires are covered with rubber, to prevent all contact, except where required. Planté substituted lead wires for the platinum wires used before then, which is an important saving.

When covering several pieces at once it is prudent to join each of them to the negative pole by an iron or lead wire of a size suitable to the piece; this wire melts if an internal short circuit takes place and then withdraws the piece automatically from the circuit.

The moulds are given a metallic coating by means of pure plumbago which must be applied to the mould with a plate brush or soft polishing brush, wax requiring very soft brushes. Metallising may also be effected by the wet process with a solution of nitrate of silver painted upon the object in two or three coats and reduced by a solution of phosphorus in bisulphide of carbon. This wet process is suitable for delicate and intricate objects, laces, flowers, leaves, moss, lichens, insects, &c.

Baths.—Whatever the work in hand may be, the bath is always the same and is prepared as follows:—

A certain quantity of water is put into a jar to which

8 to 10 parts in 100 of sulphuric acid are added in small quantities, stirring continually; afterwards as much sulphate of copper is dissolved in the acidulated water as it will take at the ordinary temperature, stirring continually; it is always used cold and must be maintained saturated by the addition of crystals or suitable anodes. It should be put into jars of clay, porcelain, glass, or hard brown earthenware or indiarubber; for large baths wooden vats may be used lined inside with a thin coating of indiarubber, marine glue, or varnished sheets of lead. Never line with iron, zinc, or tin.

Rate of Deposit.—This may be varied within considerable limits without greatly affecting its quality.

In printing work, for instance, about 1 gramme of copper per hour per square decimetre is deposited and the operation lasts 24 hours, but the same deposit may be obtained in 12 and even in 8 hours. A current of 2·6 ampères per square decimetre of surface to be covered gives a magnificent deposit of 7 grammes per hour per square decimetre. An ampère-hour, that is to say, a current of one ampère for one hour, passes 3600 coulombs of electricity, and deposits 1·19 gramme of copper. These few figures enable the current, the rate of deposit, and the duration of the operation to be regulated, according to the surfaces to be covered and the thickness desired.

General Management of the Baths and Currents.—When the solution is too weak and the current too strong, the deposit will be black; when the solution is too concentrated and the current too weak, the deposit is crystalline. A fine deposit of flexible metal called by Smee "reguline" will be obtained under mean conditions. The stratification of the liquid and the circulation which is produced in the interior of the bath by the decomposition of the anode and the deposition on the cathode, produce long vertical lines. It is necessary therefore to move the pieces about in the solution as much as possible so as to keep the bath homogeneous. Large baths have an advantage in this respect. A great distance between the anodes and the cathodes produces a more regular deposit; this is especially necessary for small

objects, but loss is thereby entailed in the quickness of the deposit or a more powerful current is necessary. The same bath may be used for several objects, each joined to a separate electric source, by using a single anode joined to all the positive poles of the different sources. The surface of the anode in general must be equal to the surface of the cathode; too small an anode impoverishes the solution, too great an anode enriches it; experiment in each case indicates whether it is to one's interest to produce one effect or the other.

Simple Apparatus for Amateurs.—A simple apparatus, and moderate in price, may be made without difficulty for covering with copper small plane surfaces or for the reproduction of medals or bas-reliefs of small size, by placing the sulphate of copper solution in an earthenware or porcelain jar, in the centre of which is a porous pot holding an amalgamated zinc and a solution of sulphuric acid and water of 2 or 3 in 100. At the top of the zinc a brass rod is fixed, supporting a circle of the same metal, the diameter of which is between that of the containing vessel and that of the porous pot; from the brass circle the pieces are suspended in such a manner that the parts to be covered are turned towards the porous pot.

Two small horsehair bags filled with crystals of sulphate of copper are suspended in the solution of sulphate of copper to maintain its saturation.

Simple amateur baths are also constructed of indiarubber, in the shape of a flat rectangular case, less fragile and easier to move.

The size varies with the objects to be covered.

Thin Adhesive Deposits, or Electro-plating.

Thin adhesive deposits are at present obtained from all the metals and on all the metals. We shall only refer to those most important to the amateur, that is to say, the deposition of gold, silver, or nickel, when the object is to protect from atmospheric or other influences, or to beautify certain articles.

Good and lasting deposits are only obtained after a series of most important operations of thorough cleansing, the object of which is to prepare the metallic surface to receive the deposit, and to insure as perfect an adhesion between the two metals as possible. Too much stress cannot be laid upon the necessity of this cleansing; most failures may be attributed to bad cleansing, in the same way as nearly all failures in photography are due to defective cleaning of the glass plate.

Cleaning.—Whether the deposit is to be of gold, silver, or nickel, the following are the operations to be performed to obtain an adherent deposit, whether dull or bright.

1. *Removal of Grease.*—Warm the pieces before a slow fire of charcoal, coke, or, better still, in a dull red stove. Delicate or soldered articles should be boiled in a solution of caustic potash dissolved in ten times its weight of water.

2. *Scouring.*—The scouring bath is composed of 100 parts of plain water to 5 to 20 parts of sulphuric acid; the articles may generally be put in hot. Leave them in the bath until the surface turns to an ochre-red tint. The articles cleaned of grease by potash should be washed and rinsed in water before being scoured.

From this moment the articles must not be touched with the hand; copper or glass tongs must be used, and for very small articles earthenware or porcelain strainers.

3. *Spent Nitric Acid Bath.*—This is nitric acid weakened by previous use. The articles are left in until the red coat disappears, so that after rinsing they show only a uniform metallic tint. Rinse thoroughly.

4. *Strong Nitric Acid Bath.*—The articles, well shaken and drained, are put into a mixture of

Nitric acid of 36° Baumé	100 volumes.
Chloride of sodium	1 volume.
Calcined soot (lampblack)	1 ,,

The articles must only remain a few seconds in the bath Avoid over-heating or using too cold a bath. Rinse thoroughly with cold water.

5. *Strong Nitric Acid Bath, to give a bright or dull appearance.*—For articles required to have, when finished, a bright appearance, plunge for a second or two, moving them rapidly about, in a cold bath of

Nitric acid	100 volumes.
Sulphuric acid	100 ,,
Common salt, about	1 volume.

Rinse quickly in water.

If a dull or "mat" appearance is desired, the bath is composed of

Nitric acid	200 volumes.
Sulphuric acid	100 ,,
Sea salt	1 volume.
Sulphate of zinc	1 to 5 volumes.

The duration of immersion varies from 5 to 20 minutes, according to the dulness desired. Wash with plenty of water. The articles look earthy and disagreeable, which disappears by plunging them for a moment into the brightening bath and rinsing quickly.

6. *Nitrate of Mercury Bath.*—Plunge the cleaned articles for a second or two into a bath of

Plain water	10 kilos.
Nitrate of mercury	10 grammes.
Sulphuric acid	20 ,,

Stir up before using. The bath should be richer in mercury if the articles are heavy, less rich if light. A badly cleaned article comes out tinted in various shades, and without metallic brightness. It is better to throw a spent bath away than to strengthen it. After passing through the mercury, the article must be rinsed and put at once into the plating bath.

Gilding.—Small articles are gilded hot, large pieces cold.

Cold Cyanide of Gold and Potassium Bath:—

Distilled water	10 litres.
Pure cyanide of potassium	200 grammes.
Pure gold	100 ,,

The gold, transformed into chloride, is dissolved in 2 litres of water, the cyanide in 8 litres; mix the two solutions, and

boil for half an hour. The richness of the bath is maintained according to requirement by adding equal parts of cyanide of potassium and chloride of gold, a few grammes at a time. If the bath is too rich in gold, the deposit is blackish or deep red; if there is too much cyanide, the deposit is slow and grey. The anode must be entirely submerged in the bath, suspended by platinum wires, and withdrawn directly the bath is not in action.

Hot Gold Bath.—Zinc, tin, lead, antimony, and the alloys of those metals are better previously covered with copper. The following are the formulæ for the other metals per 10 litres of distilled water:—

	Silver, Copper, Bronze, Alloys rich in Copper. grammes.	Castings, Iron and Steel. grammes.
Crystallised phosphate of soda	600	500
Bisulphide of soda	100	125
Pure cyanide of potassium	10	5
Pure gold transformed into chloride	10	10

Dissolve the phosphate of soda hot in 8 litres of water, let the chloride of gold cool in 1 litre of water, mix little by little the second solution with the first, dissolve the cyanide and bisulphide in 1 litre of water, and mix this last solution with the other two.

The temperature of the bath may vary between 50° and 80° C. A few minutes are sufficient to produce a good deposit; an anode of platinum is used; the anode not sunk deep into the bath gives a pale gold deposit; deeply immersed, it gives a red colour. The bath may be kept up by successive additions of chloride of gold and cyanide of potassium, but after long usage a red or green deposit is obtained, according as it has been used most to gild copper or silver. It is preferable to renew the bath instead of enriching it.

Rapidity of Deposition.—In a bath holding 1 gr. of gold per litre, about 30 centigrammes per hour per square decimetre may be deposited, but this average figure may vary greatly.

Silvering.—For amateurs a bath of 10 gr. of silver per litre is sufficient; dissolve 150 gr. of nitrate of silver, equi-

valent to 100 gr. of pure silver, in 10 litres of water, and add 250 gr. of pure cyanide of potassium. Stir up until completely dissolved, and filter. Silvering is generally done cold, except for small articles. Iron, steel, zinc, lead, and tin, previously coppered, silver better hot. The cleaned articles are first put into the nitrate of mercury bath and moved continually. When there is too much current the pieces become grey and blacken, then gas is liberated. Use anodes of platinum or of silver in cold baths. Old baths are preferable to new baths. The baths are artificially aged by adding 1 to 2 in 1000 of liquid ammonia. The silver baths are kept up by adding equal parts of the silver salt and cyanide of potassium. If the anode blackens, the bath is poor in cyanide, and the deposit is too slow ; if it whitens, there is too much cyanide, the deposit is rapid, but does not adhere. The deposit is normal and regular when the anode becomes grey when the current passes, and white again when it ceases.

Nickeling.—Nickel is a white metal, little oxidisable, and may be applied in coats of varying thickness to the other metals, especially to iron, and to its derivatives, and to copper.

The first attempts to nickel metals were due to Smee, and afterwards to Becquerel. But Smee and Becquerel's experiments gave insufficient results, while Dr. Isaac Adams of Boston was the first to make known a really practicable and commercial process of depositing nickel. This was published in 1869, and since then a great number of nickel-plating works have been put up in the United States. The first European nickel-plating factory was established in Paris by Adams and Gaiffe, but a great deal of nickel-plating is now done in London.

Nickel is much used to cover copper and its alloys, brass, bronze, gun-metal and bell-metal ; also iron and its derivative, steel. Its application to the other metals is of little importance, and necessitates operations and preparations as long as they are tedious.

A vat and a battery are necessary to nickel-plate ; the

vat to receive the bath and the articles to be covered ; the battery to decompose the bath.

The Vat.—For amateurs the vat should be of glass, or, in default, porcelain or earthenware may be used, or a case lined inside with an impermeable gum.

The Bath.—The best nickel bath is prepared by dissolving to saturation in hot distilled water, nickel sulphate and ammonium free from oxides of alkalies and alkaline earthy metals. The proportion of salt to dissolve is 1 part by weight to 10 of water. Filter after cooling, when the bath is ready for use.

The Battery.—A convenient battery for amateurs, but not for industrial purposes, is the bichromate of potash bottle battery.

Double fluid bichromate batteries, or the Lalande and Chaperon, Holmes, or Emmens batteries are also suitable.

Preparation of the Bath.—When the bath is ready and the battery set up, the wires from the latter are joined by means of binding screws to two metallic bars resting on the edge of the vat. The bar joined to the positive pole of the battery supports, suspended from a copper hook, nickel-plated, a plate of nickel constituting the soluble anode which restores to the bath the metal deposited on the cathode by the electrolytic action. From the other bar (zinc or negative pole) the articles to be nickeled are suspended.

Preparation of the Articles.—But before putting the articles into the bath, they must undergo a series of necessary operations if a good result is to be obtained. Nickel being a hard metal, and difficult to burnish, it is advisable that the articles should be well polished before being put into the bath, if a nice polish of the deposited metal is to be obtained.

Removal of Grease.—This is effected by scrubbing the articles to be plated with brushes soaked in a hot solution of whiting boiled in water and carbonate of soda. When the pieces are perfectly freed from grease, they may be easily and equally wetted with plain water.

Scouring.—This is effected either by chemical or mechanical means.

Copper and its alloys are cleaned well in a few seconds by dipping in a bath composed of 10 parts of water by weight, and 1 part of nitric acid. Or for rough articles a more energetic bath may be used, consisting of 2 parts of water, 1 part nitric acid, and 1 part sulphuric acid. Iron, steel, and polished castings are cleaned in a bath of 100 parts of water to 1 part of sulphuric acid. The articles should remain in the cleaning bath till the whole surface is of a uniform grey tint. They are then rubbed with powdered pumice stone till the solid metal appears. Iron, steel, and rough castings require a longer series of operations. These metals are left for three or four hours in the cleaning bath, then scrubbed with sand well ground and sifted.

Both these operations are continued until the complete disappearance of any trace of oxide or rust on the surface of the articles.

The pieces prepared and ready to be put into the nickel bath, are plunged for a moment in a liquid of the same composition as that used for cleaning them, when they are quickly washed in plain water and afterwards in distilled or filtered rain water. When they come out of this last bath they are immediately put on the hooks and immersed in the plating bath.

Management of the Current.—It is prudent to watch the progress of the operation and to regulate the current of the battery. If the current is too strong the nickel is deposited in the form of a grey or even black powder. When the bottle battery is used it is easy to modify the current, by sinking the zinc more or less into the exciting liquid.

An hour or so is sufficient to render the coat of nickel deposited sufficiently thick, and in a condition to stand proper polishing ; but the articles may with advantage be left for five or six hours in the bath, if it is desired that they should be very thickly coated.

Rate of Deposit.—In a bath holding 10 gr. of nickel per litre, about 1·8 gr. of nickel must be deposited per hour per square decimetre to obtain a good result.

When the articles are taken out of the bath they are washed in plain water and dried in hot sawdust.

Polishing.—Polishing finishes the process and gives the brilliant appearance of silver so much sought after. This is the more easily and perfectly obtained when the articles have been polished before being put into the bath.

To polish the articles they are taken in the right hand and rubbed rapidly backwards and forwards on a strip of cloth soaked in polishing powder boiled in water, the cloth being firmly fixed at one end and held at the other in the left hand. The hollow parts are polished by means of cloth pads of various sizes fixed on sticks. These pads must be dipped into the polishing paste when using them.

The articles when well brightened are washed in water to get rid of the paste and the wool threads, and finally dried in sawdust.

CHAPTER XII.

ELECTRIC RECREATIONS.

ELECTRICITY, by its invisibility, instantaneous action, and the peculiar characteristics of its manifestations, lends itself to a mass of experiments and singular phenomena, some of which we will now describe with the idea that amongst the numerous ways of self-instruction, those which instruct whilst they amuse must take a high rank.

With this view we will review successively telephonic curiosities, melographs, jewels, illusions, and toys.

TELEPHONIC CURIOSITIES.

Under this title we give some telephone experiments remarkable for the nature of the receiver employed. We know that the telephone transmitter, whether magneto or microphone, is an apparatus designed to set up undulatory currents synchronous with the vibrations which gave rise to them, and that these electrical waves react on a receiver which again transforms it into sound-vibrations more or less weakened, but sensibly of the same nature.

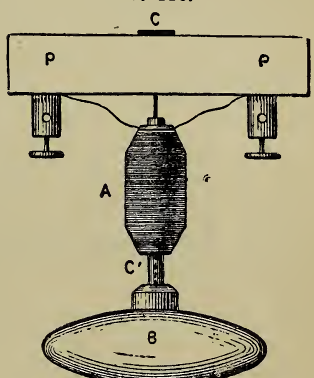
The Bell magneto telephone is generally used as receiver, but as a matter of fact, none of the parts of which it consists are essential for a transmission, which if not perfect is at least workable.

Telephones without Vibrating Diaphragm.—The first simplification to which a Bell telephone may be submitted consists in the suppression of the vibrating diaphragm, when speech is no longer distinctly audible if the transmitter is a magneto telephone, but if a carbon transmitter and

induced currents are used conversation may be carried on. The sound is, however, very weak, but Count du Moncel who made a great number of experiments on this subject, proved that the effects are the more pronounced the more strongly the core is magnetised and its bulk lessened. By using a well magnetised watch-spring and a small coil of fine wire on its extremity, Du Moncel succeeded in hearing speech even when a Bell magneto telephone was used as transmitter.

Telephone without Diaphragm and without Magnet. Ader's Experiment.—The presence of a magnetised core in the telephone receiver is not absolutely necessary; the electrophone of Ader has very small electro-magnets of soft iron. Making experiments with this apparatus Ader was led to construct a receiver consisting of a simple iron rod 1 millimetre in diameter wrapped with a coil of fine wire, and he was enabled to transmit speech under these conditions with great distinctness. The small iron core was stuck on a block of wood, and he found that by applying to the other free end a heavy mass, the intensity of the sound was more than doubled.

Fig. 116.

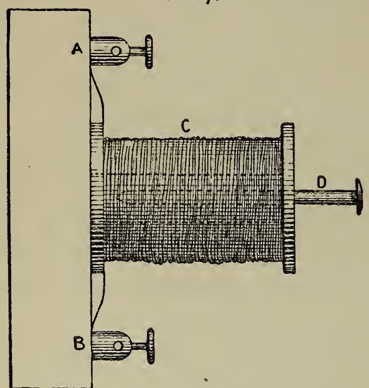


He then constructed the simple telephone receiver shown in Fig. 116, in which B is a door handle, C C a soft iron rod 1 millimetre in diameter, fixed on a deal board 2 inches square and a small coil A wound on a goose-quill. The transmitter was a carbon transmitter of any description. With this little instrument a very amusing spiritualism experiment may be made by fixing the iron rod C C underneath a table, hiding the conductors carefully and letting a confederate speak into the transmitter placed in another room some distance away. If the experiment be made in silence at a late hour of the night, the whole table speaks, and it may be heard anywhere round the table if the ear be brought close to it. This experiment produces

the most singular effects on credulous and impressionable persons.

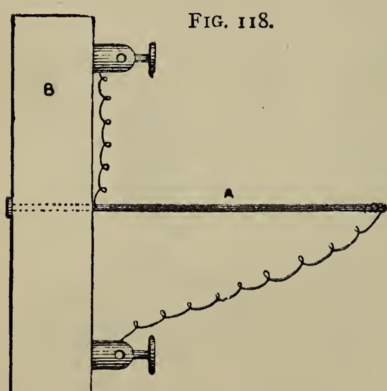
Ader, continuing his experiments, constructed another telephone still more simple; it is made of a piece of wood A B, Fig. 117, and of a bobbin C fixed to it, on which a fine wire is wound very loosely. Such an apparatus will speak when actuated by a carbon transmitter and three Leclanché cells. If the spirals are too tight or covered with shellac, the telephone does not speak, but by introducing a nail D into the bobbin, speech will at once be heard distinctly. Withdraw the nail and the telephone ceases to act.

FIG. 117.



Telephone without Diaphragm, Magnet, or Coil.—The following telephone receiver is still simpler. It consists of a soft iron rod A, Fig. 118, fixed in a wooden board B, with a heavy metallic mass at the other end of A. By holding the board B to the ear speech may be reproduced by using a carbon transmitter. De la Rive in 1846 reproduced sounds under similar conditions with interrupted currents, but Ader first reproduced articulate speech by this means.

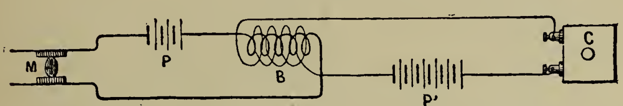
FIG. 118.



Dunand's Speaking Condenser.—A condenser is a number of sheets of tin-foil each separated by paraffined paper or mica. Such an arrangement makes an excellent telephone receiver. Dunand by the following means makes it speak,

On the primary circuit are included a microphone M, Fig. 119, a battery P, and a small bobbin B ; the secondary wire of the coil B is in circuit with the line, and a battery of several elements P′, the two free ends being joined to the terminals of a small condenser C, which forms the receiver. By speaking into the microphone the primary current becomes undu-

FIG. 119.



lating and induces currents in the fine wire of the coil, which vary the charge of the condenser. These undulating charges and discharges of the condenser make it speak, but the cause of the phenomenon cannot yet be perfectly explained.

The battery P is indispensable; the induced currents, by increasing or diminishing the current of the battery, vary the charge of the condenser, but the direction always remains the same. This is up to the present a *sine quâ non* of the speaking condenser, and however the connections may be altered, if this point be satisfied the condenser will have this faculty of articulation in a greater or less degree. The battery P consists of four ordinary Leclanché cells, two in tension and two in quantity.

The coil B has a primary wire of about ½ ohm resistance and a secondary of 250 to 300 ohms.

The number of cells in the battery P′ to charge the condenser varies with the number of condensers used.

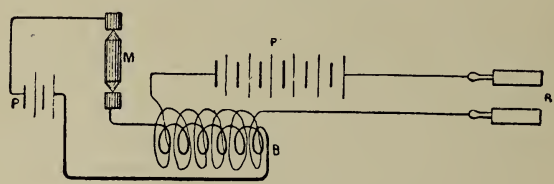
Telephonic transmission without receiving apparatus.—We saw how Dunand made the condenser speak, but it is possible to greatly simplify this, as was demonstrated by M. Giltay at the Paris Observatory on the occasion of the Easter meeting of the French Physical Society.

An inspection of Fig. 120 will explain the connections. The primary circuit includes a battery P of two or three large Leclanché cells, or of one or two small accumulators, an Ader transmitter, and the primary wire of a small induction coil B.

The second circuit consists of the secondary wire of the coil B, a battery P′ of ten to twelve Leclanché cells, and the line wire terminating at R in two ordinary medical coil handles.

If some one speaks or sings into the transmitter M, and two persons A and B each take one of the handles R in the bare hand, it is sufficient for A to apply his other hand, gloved, to B's ear, or *vice versâ*, or even simultaneously for A or B, or A and B together, to hear a voice coming out of the glove.

FIG. 120.



This experiment is similar to Dunand's speaking condenser. A's hand and B's ear constitute the two plates of a condenser, the glove acting the part of the dielectric.

Repeating Giltay's experiment at the laboratory of the School of Physics and Chemical Industry of Paris and varying its arrangements, the glove was replaced by a sheet of ordinary paper; then two persons A and B holding the handles R and applying the ear of one to that of the other, interposing the sheet of paper, heard tunes and words coming out of the paper. Finally the paper, that is to say the dielectric, was entirely done away with and sounds heard direct by including the hearer or hearers in the circuit, Fig. 121. One of the most curious phases of the experiment is to make a chain of three persons, A, B, and C, when the third person C hears the hands of A and B speak. A and B each holds one of the circuit wires and applies his disengaged hand to the ear of C. It is even possible, but the experiment requires absolute silence, to make a sort of telephonic chain enabling five or six persons to hear at once; A putting his hand to B's ear, B his hand to C's ear, and so on to the last, who

closes the circuit by holding one of the handles, the other being held by A.

FIG. 121.

It is difficult to explain clearly how these telephonic

transmissions are effected without a receiver. All that can be concluded is that the ear is an instrument of incomparable delicacy, and of an exquisite sensitiveness, seeing that it can perceive such excessively feeble vibrations as there must be on this telephonic chain.

Melographs.

The name of melograph is applied without distinction, and wrongly, in our opinion, to apparatus which register music and to those which reproduce it mechanically. We will describe two systems in which electricity plays an important part.

Roncalli's Melograph, or Automatic Recorder of Musical Compositions.—The first question is, Are recorders of musical improvisoes useful, and can they render real service to musicians by inscribing automatically and instantaneously in a suitable notation, easy to read and ultimately to transcribe, all melodies passing through the brain of the artist at the moment of inspiration?

The opinions on this subject are very divergent. It appears, however, that a good recorder of musical improvisoes, useless according to some, indispensable according to others, may nevertheless be of some use, and we will therefore describe a system exhibited at the Vienna Exhibition in 1873 by Roncalli, which offers, if not a perfect solution, at least a first important step in that direction.

The first electrical music-recorder was invented and constructed in 1856 by Count du Moncel. After some experiments the apparatus was, perhaps prematurely, abandoned, as its performance did not come up to what was required. But we must not forget that twenty-eight years have since passed, and that batteries were not so simple and not so generally known as they are to-day. An apparatus compelled to have recourse to electric batteries was at that time almost proscribed, especially by those little accustomed to their handling.

At the present moment the question may be reopened and the solution attempted with greater chance of practical

success. Roncalli's apparatus, as was that of du Moncel, is based upon the chemical reactions produced by the electric current.

It is known that a steel point gliding over a sheet of paper saturated with a solution of yellow cyanide of potassium and nitrate of ammonia leaves no mark, but when an electric current passes through the paper and the metallic point, the latter is attacked; a salt of protoxide of iron is formed, which in presence of the cyanide causes a black precipitate leaving a mark.

The colours of the marks vary with the nature of the point: thus, for example, copper or its alloys leave a red mark; cobalt, a brown; bismuth, an invisible mark turning canary yellow in water; nickel and chrome leave green marks; silver, an invisible mark which turns brown when exposed to the light.

Roncalli's melograph is founded on these properties. It consists of a comb with fixed and very close metallic teeth, traversed by the current of the battery. Each tooth is joined by a wire to a key of the piano or the harmonium.

The teeth corresponding to the natural tones are of steel, those which correspond to the half-tones of brass.

A roll of prepared paper drawn by a clockwork movement passes at a uniform speed underneath the metallic points, and shows the mark of the teeth the keys of which are lowered; the length of the marks on the paper roll is proportionate to the duration of the corresponding sounds, that is to say, the value of the note. Fig. 122 represents the whole system arranged on a harmonium, and Fig. 123 shows the details of the instrument itself, seen on the right of Fig. 122. The case on the left is a clockwork arrangement for unrolling the paper, the speed of which is regulated by fans; the pyramidal-shaped case in the middle is a metronome, the use of which we will presently explain.

The recorder, Fig. 123, consists of a metallic cylinder A, joined to the zinc pole of a battery sufficiently powerful to decompose the nitrate of ammonia (Roncalli uses three or four chloride of sodium elements). At B is a comb, movable

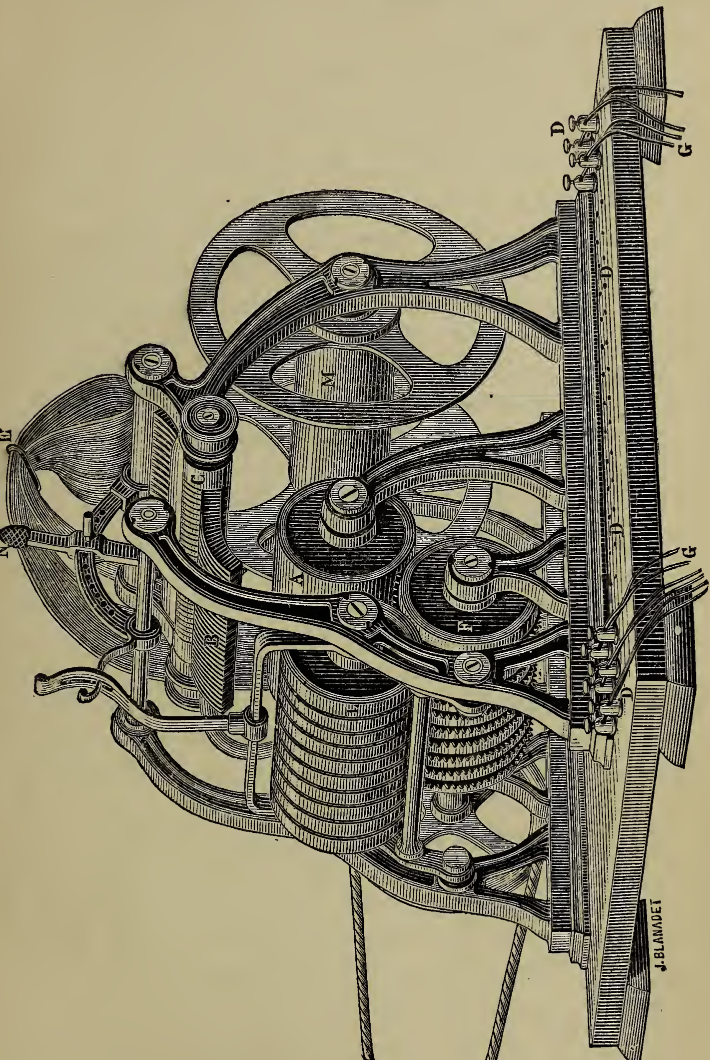
round the axis C; this comb has forty-one teeth, each of which communicates by an insulated wire E with a terminal D, from whence a second insulated wire G joins it to one of the keys of the piano. The handle M enables the comb B at will to be brought up to or away from the cylinder A.

FIG. 122.

The paper is worked by the two cylinders F and L, between which it passes. The cylinder F is driven by clockwork (Fig. 123) by means of pulleys and a cord. There are nine rows of teeth on its surface, which press by means of a spring into an equal number of grooves cut on the circum-

ference of the cylinder L. The barrel M carries the prepared paper, which passes between the cylinder A and the comb B,

Fig. 123.



and between the two cylinders F and L, which unroll it at a uniform speed. A brass strip is stretched under the keys all along the finger-board of the piano or harmonium, and this

strip is connected to the positive pole of the battery. Small springs fixed under each key make contact between this strip and the metallic pieces, to which come the conductors G, joined to the corresponding terminals D of the receiver.

It will now be readily understood how the apparatus works. By pressing one or several notes, the current passes into the corresponding teeth of the comb and imprints on the paper roll a series of marks, the position of which indicates the height, the duration, and the length; the line is black for a natural tone, red for a sharp or flat. For a harmonium of five octaves a comb of sixty-one points is necessary, and as the points are about 2 millimetres apart, a breadth of at least 112 millimetres (about $4\frac{1}{2}$ inches) is required. To reduce the width of this roll Roncalli repeats the two end octaves, so that the first is written over the second and the fifth over the fourth. Thirty-nine points and a roll of paper $3\frac{1}{4}$ inches wide are then sufficient.

It now remains to mark the time. For this purpose Roncalli introduces into the comb two other teeth, made of an alloy of bismuth and copper, which leave orange-coloured marks. In the original arrangement the musician sent the current to these points by pedals, thus making two orange marks whenever the time was changed, but this was a great nuisance to the player. At present Roncalli uses a metronome, the action of which is automatic and perfect, provided the musician himself keeps the time indicated by the metronome.

Practically this is at least just as inconvenient as in the first case, or perhaps more so, as in one piece different times follow each other rapidly, and the musician may not be able under the influence of his inspiration to stop himself to change the motion of the metronome and to adapt it to the changed rhythm of the melody.

In fact the registration of the time, or more correctly of the separation of the times, does not appear to us to have been solved by any of the known apparatus.

The use of chemical papers necessitates certain precautions to which an artist cannot easily conform; the oxidation and

the unequal wear and tear of the points also require a certain maintenance which render the apparatus very delicate to manage in spite of its simplicity.

Carpentier's Repeating Melograph.—We cannot do better, in order to describe this curious and original instrument, than let M. Carpentier speak himself:—

"The desire to add to one's talents one which one does not possess is, perhaps, an active incitement to the spirit of invention. As far as I am concerned, I may say that my pronounced liking of music added to my complete ignorance of playing any instrument has always induced me to look to mechanical contrivances for the means of satisfying my natural liking. Musical boxes and organs have always delighted me, and if it were not for the monotony resulting from the repetition of the same airs, I would willingly turn a handle for hours in order to enjoy, without requiring assistance from any one, the pleasure which the sensation of listening to the measure and rhythm of the melody gives me.

"Mechanical pianos, with their limitless series of perforated wood or cardboard sheets, would be a grand help to dilettanti like me. But they are cumbersome, very dear, and at the price at which the pieces of music are sold the getting together of a musical library would be ruinous.

"All these considerations have repassed a thousand times through my mind, leading me some years since to invent a small apparatus which I have called the melophone, and which is made as follows:—

"A small closed rectangular case; inside, under the lid and close together, thirty very small harmonium reeds, requiring little room and fixed in the ordinary manner; above each reed a passage cut in the common sounding-board and ending in a small orifice on the top of the box. On one side of the box is a tube enabling air to be pumped in by means of any kind of bellows.

"The thirty small holes are arranged in a perfectly straight line, and a musician, with thirty fingers and some practice, might make something of it. But I have only ten fingers and no practice at all, so that I must have recourse to some other

device to get from my melophone what I expect from it. By means of revolving cylinders worked by a crank handle

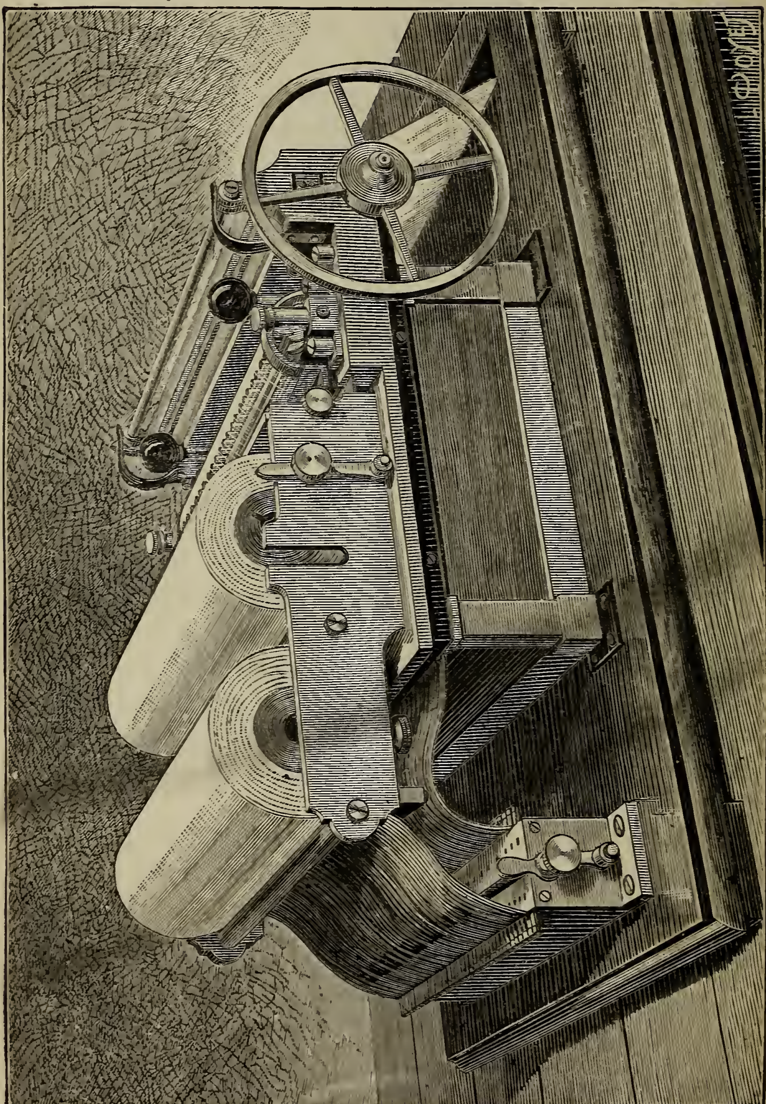


Fig. 124.

I pass over the perforated surface of the case, in a direction at right angles to the line of holes, a broad band of paper,

which I take care to keep well pressed flat on the top of the holes. The reader will already have guessed that the paper was pierced with long and short holes of a special arrangement, so that in the movement these holes are brought exactly over the various openings, giving vent to the air through the reeds, and that the melophone plays automatically the piece previously inscribed.

"The means being simple, the instrument was not perfect, but it was something, and for me, much. I have since seen similar instruments made in America. I do not know, however, to whom the priority of invention belongs.

"However, in possession of my melophone, I had to consider the making of my rolls. The translation of ordinary music into such language occupied my leisure in the winter evenings. I soon saw that this would be a long and tedious operation, and set to work to simplify it by getting musicians of my acquaintance to prepare my rolls for me, without their knowing what they were doing. I combined a melograph to write down the pieces played on a piano, but using characters which my melophone could read, that is to say, by perforating the paper. I would add that my melophone itself was transformed, I made it able to take broader bands and even to work the instrument itself, piano or harmonium, on which was played the piece inscribed by the melograph.

"My apparatus were exhibited at the International Electric Exhibition. Before describing them let me give the reader a glimpse of the results obtained.

"1. A composer sits down at my piano and plays some improviso or fleeting inspiration unpublished. He rises. I turn three buttons and the instrument at once repeats automatically the piece it has once heard or rather played by the fingers of the artist.

"2. Together with the merit of an author, that of the performer has also to be considered, and the same piece, played by two persons, produces very different effects. My instrument is very docile, it preserves and reproduces the style of each. It goes even further, it plays false notes.

"3. Several persons come to me to play a concerto; I get

them a violin, violoncello, flute, hautboy, piston (all provided with my system). The piece is finished. Listen : my instrument, past-master in the art of transcribing, plays at once on a piano or an organ the concerto, perfectly transcribed, and you hear all its parts.

"4. Finally, the last very useful application : I arrange my roll in a printing machine, and the piece, instead of being played, comes out written in ordinary characters. This musical printer is at present only projected, but it is realisable.

"Let me now describe the apparatus. First of all, the harmonium and the melograph must be distinguished. Fifty wires, hidden under the floor, place the two instruments in communication.

"*Inscription.*—The fifty harmonium keys are so arranged that when pressed down an electric current is sent into the corresponding wires. Each current, received in the melograph, works a series of perforating tools, thus recording the motion of the key sending it, on a roll of paper passed through the apparatus at a uniform rate.

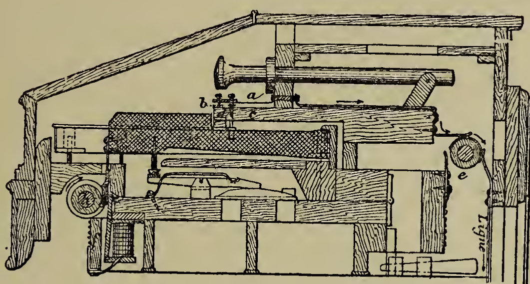
"*Repetition.*—On again unwinding the roll, previously put back to the original position, fifty small silver wires try to make contact through the paper with a metallic cross-piece, against which they press the paper. As soon as a hole enables a point to touch the cross-piece, a current circulates in one of the line wires, and acting on the lowering mechanism of the corresponding key, determines the emission of the sound, maintained until the substitution under the wire of a blank.

"This general explanation shows the connection between the different parts of the apparatus, and I may now separately describe the principal parts, as shown in Figs. 125 and 126.

"Underneath each key a spring *a*, Fig 125, tends to place itself on a silver band *b* running along the cross-piece *c*, which covers the back part of the finger-board. A pilot *d*, working freely in a small cylinder, holds the spring up, by pressing against the key, when this is at rest. When the key is lowered, the pilot follows its motion, and the spring being

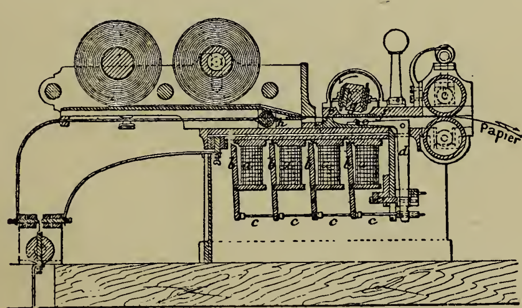
freed, makes contact. Two regulating screws enable the course and the tension of the spring to be varied. The current thus started by a key, is sent along the line wire passing through a commutator *e*.

FIG. 125.



"The currents caused by the harmonium and received in the melograph, produce there the motion of the parts by means of electro-magnets, Fig. 126, of a special form. The space in the apparatus available for the necessary organs being very limited, the electro-magnets form a battery in four rows in

FIG. 126.



echelon. The motion of the armatures *b* is transmitted by the rods *c* to the bent levers *d*, and at the end of the horizontal arm of each lever is an essential part of the apparatus—the *goffer e*. The name explains its use: it is pressed on the paper, and leaves there the record of the pressure of the player on the keys of the harmonium.

"The goffer forces the paper to penetrate into one of the mortices cut in the plate *f*, under which the band passes, and thus brings it up to a two-edged cutter revolving at great speed, thus cutting out all the indentations made by the goffer.

"This is the action of the recording apparatus, and, of course, a complete regulating system had to be adopted.

"To play from the bands, the melograph causes currents, and the harmonium receives them. The switch *e* enables the line wires to be put in connection either with the sending springs, or with the receiving organs.

"For each note of the harmonium, the principal part of the receiving mechanism is an electro-magnet *f* similar to those of the melograph. Below the finger-board, from all the keys are suspended by flexible chains small wooden shoes: these work freely in the grooves cut in a cylinder *h* revolving with a continuous and rapid motion. When a current passes through any electro-magnet it presses by means of small rollers *i* on the back of the shoe, binding it by friction against the revolving cylinder. This pulls down the corresponding key, and the note is sounded."

Electric Jewels.

Animated Electric Jewels.—Trouvé by means of electricity has obtained some novel and often startling effects.

These jewels are small figures animated by a lilliputian battery, and we will describe some.

The death's-head on the right of the bird, Fig. 127, is of gold enamelled, and has diamond eyes and a movable jaw. This makes a breast-pin.

The rabbit, also of gold, to the left of the bird, sits on its tail and holds in its forepaws two small drum-sticks with which it beats a microscopic gold clock-bell. This is also a breast-pin.

An invisible wire joins the object to the small hermetically-sealed battery of the size of a cigar, which is hidden in the waistcoat pocket, Fig. 128. If one of these jewels is carried

under the chin, and anybody looks at it, a finger is slipped into the waistcoat-pocket, setting the battery to work, when

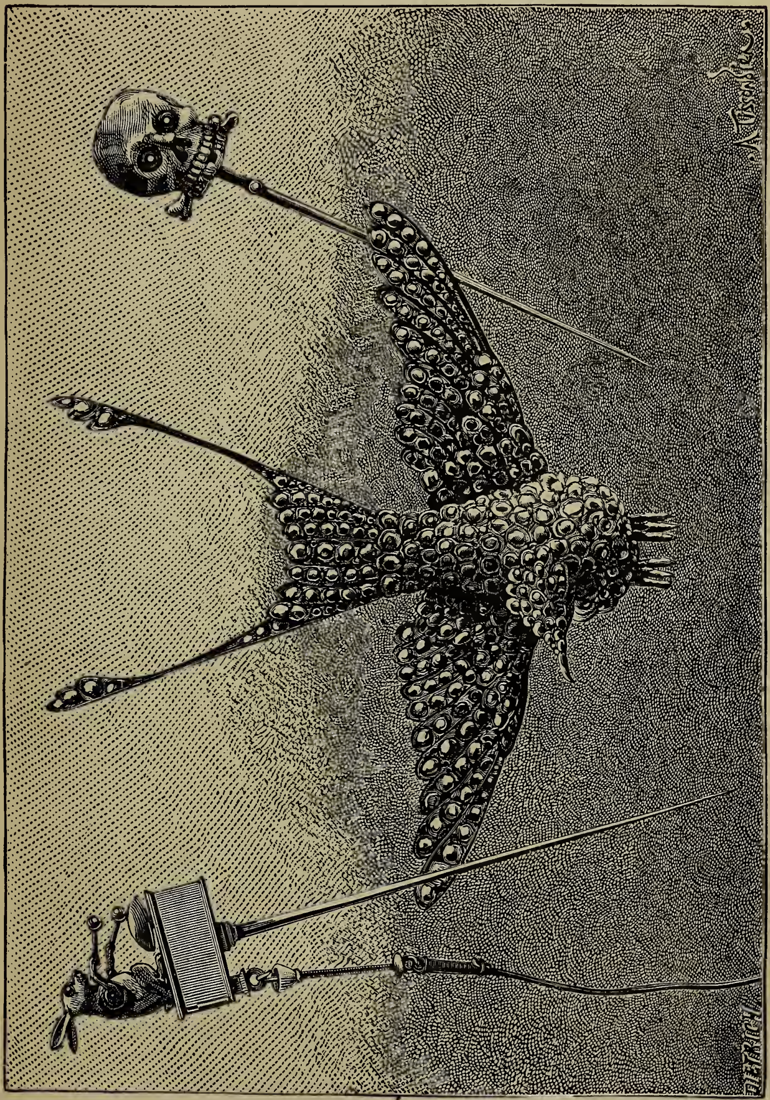
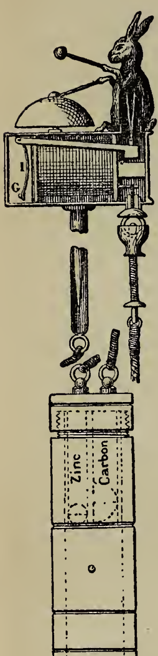


FIG. 127.

the death's-head rolls its sparkling eyes and grinds its teeth, or the small rabbit works like a kettle-drumer at the opera.

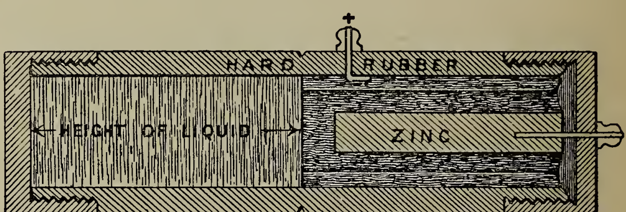
The diamond bird is carried by a lady in her hair, and she can at will make the wings of the bird flap by means of a concealed wire.

Fig. 128.



Trouvé's Pocket Battery.—These jewels are worked by a very small battery, which is easily carried in the waistcoat pocket, or in a lady's hair. The battery is a zinc carbon cell inclosed in a vulcanised rubber case hermetically closed. The zinc and carbon only extend

Fig. 129.



to the upper half of the case, the other holds the exciting liquid. As long as the case is upright the electrodes are not touched by the liquid, and no electricity is produced, nor is there any expenditure; but as soon as the case is turned upside down, or placed horizontally, the chemical reaction takes place, and continues as long as the case is in this position; but when the battery is replaced all action ceases.

Luminous Jewels.—The production of small incandescent lamps requiring only a few volts and less than an ampère, has been utilised for novel and curious effects. Since 1882 the actresses at the Savoy Theatre have been adorned with small incandescent lamps fed by small accumulators easily hidden in their dress.

Since then these applications have been enormously multiplied, and few theatres in London and the provinces are now without them, especially for the Christmas pantomimes.

Trouvé's Luminous Electric Jewels.—Fig. 131 shows how a luminous jewel is constructed. The incan-

descent lamp is fixed in the centre of the apparatus, the glasses are cut into facets making lenses and increasing the light. The two wires are hidden between the supporting pins,

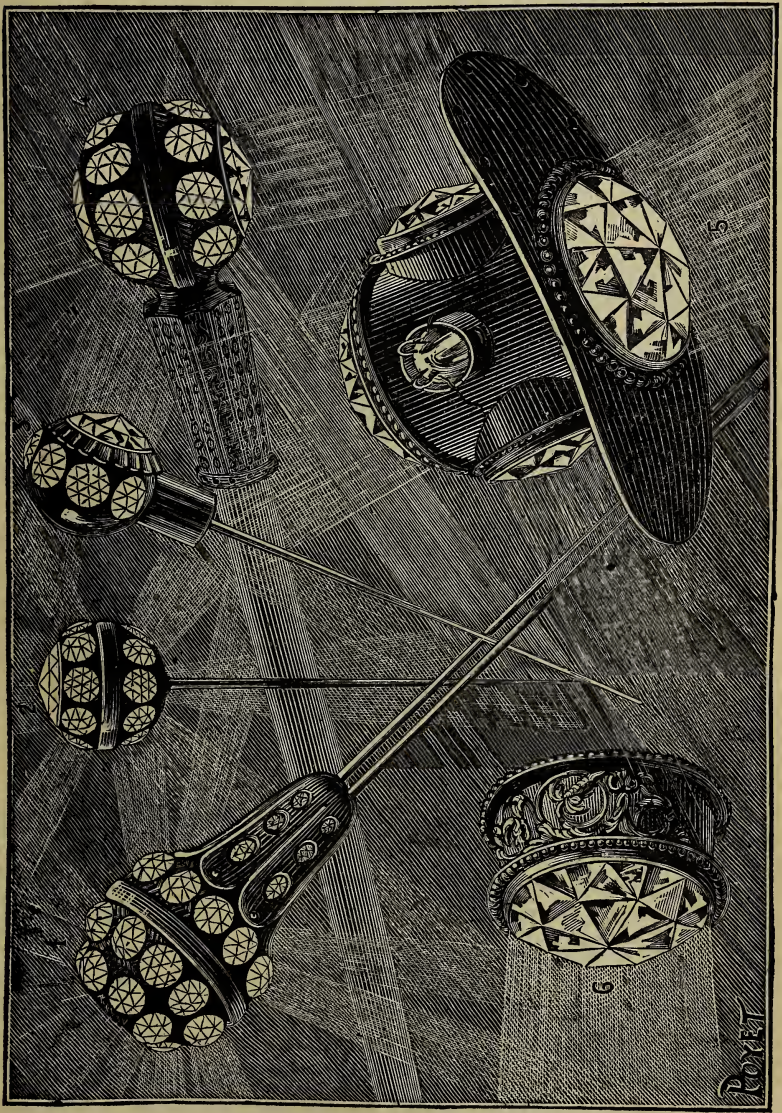


Fig. 130.

and the whole thing is easily taken to pieces to enable the incandescent lamp to be renewed when broken.

Trouvé's Pocket Battery.—The battery used by Trouvé consists of three zinc-carbon cells (two carbons to each zinc) or more, according to the effect to be obtained, the electrodes being in a solution of bichromate of potash inclosed in an ebonite trough in compartments. The lid

FIG. 131.

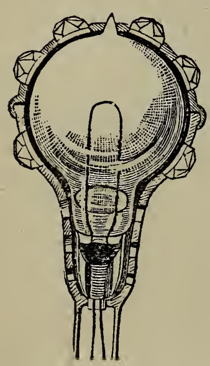
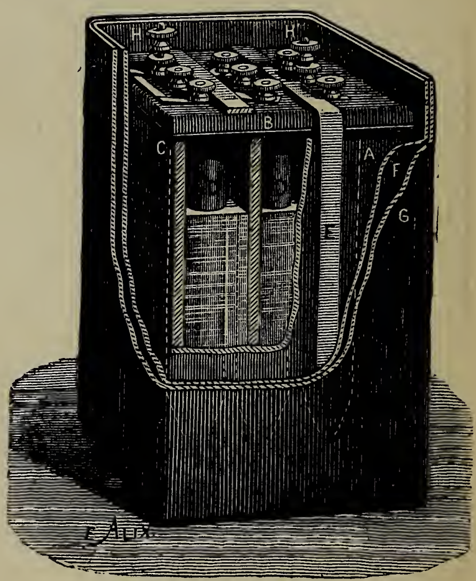


FIG. 132.

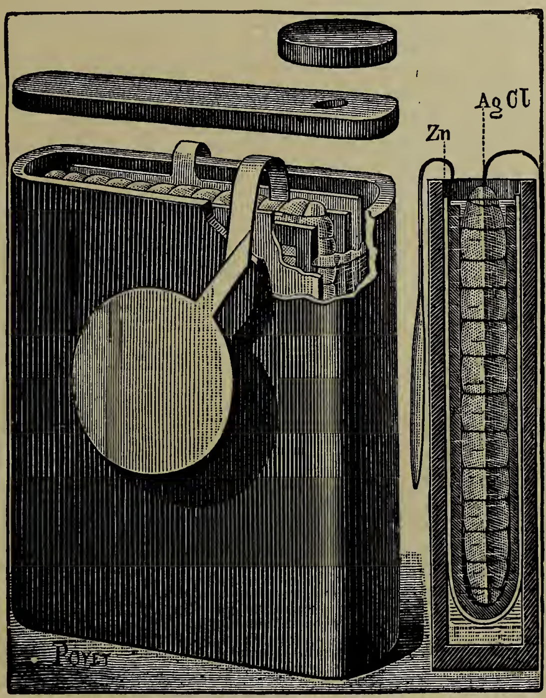


carrying the zincs and carbons is also of ebonite ; it is provided with a soft rubber washer, closing hermetically under the pressure of two indiarubber rings, one of which is shown at E. In spite of these precautions leakage of the acid liquid may take place. In order to avoid this inconvenience Trouvé incloses the battery in two hard rubber cases F and G which fit over each other like two parts of a cigar-case. The wires are connected to the two terminals H H, and a small switch enables the circuit to be closed or opened. This small battery, shown in Fig. 132 in actual size, weighs about ¾ lb. and will work for about twenty minutes with a lamp of

2 or 3 volts (small breast-pin). Larger batteries weighing under 2 lbs. may also be carried in a good sized pocket, and under favourable conditions they will light a lamp of 4 to 5 volts for nearly an hour. In other types the elements are arranged flat and can be hidden in a side pocket, as their size is not greater than that of an ordinary pocket-book.

Scrivanow's Batteries and Jewels.—This battery is shown in Fig. 133. It is contained in a guttapercha box, the electrodes being a plate of silver covered with chloride of

FIG. 133.

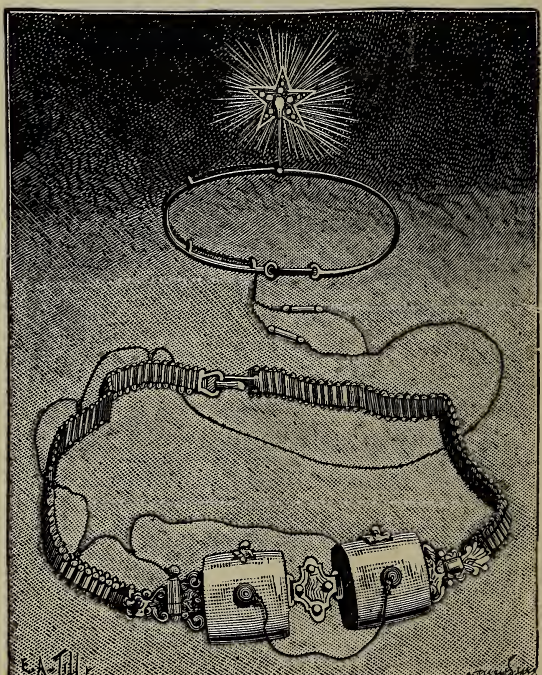


silver, wrapped in parchment paper and surrounded by a U-shaped zinc insulated by a piece of guttapercha. The section of the battery, shown to the right of the figure, shows the arrangement: *Zn* is the zinc plate, and *Ag Cl* the chloride of silver. The exciting liquid is an alkaline solu-

tion of very dilute potash. The guttapercha case with the electrodes is closed hermetically by a guttapercha lid, in which a hole is made to introduce and renew the liquid, the hole being closed by a stopper.

The dancers are equipped as follows :—The silver-plated belt passed round the waist holds two batteries, Fig. 134 ; the

FIG. 134.



diadem is placed on the head and some attendants fix the conducting wires from the two cells in series to the incandescent lamp. This done, a muslin sash is gathered round the waist hiding nearly the whole apparatus. The incandescent lamp of the diadem is fitted in front of a metallic star covered with pieces of glass imitating emeralds, and forming a reflector. On the belt a small switch is fixed, enabling the fairy at will to light or put out the lamp of her diadem.

Aboilard's Electric Jewels.—Fig. 135 represents in actual size these electric jewels, and shows how delicately they are constructed. On the right and left are two breast-pins for men: one is in the form of a small lantern, and the other represents an open flower forming a reflector. In the middle two pretty trinkets for ladies are seen, a bird and a diadem; below these is a small round switch, very convenient, and may be worked in the pocket.

FIG. 135.

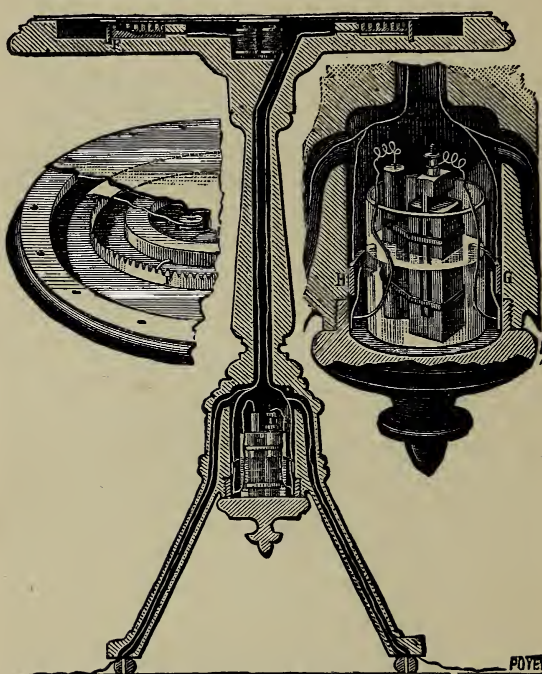
CONJURING.

Speaking Tables and Electric Insects.—The marvellous facility with which electricity lends itself to the production from a distance of mechanical calorific or luminous effects has often been made use of in some curious and amusing

effects, which simple minds willingly call supernatural, as they cannot explain them satisfactorily.

Fig. 136 is a table having the appearance of an ordinary stand, which enables one to reproduce at will spirit-rapping or sepulchral voices.

FIG. 136.



The foot of the table holds a Leclanché cell of squat form, carefully hidden in the part which joins the three feet to the upright. The table itself is in two parts; the lower part is hollowed out and the upper is a thin lid not more than $\frac{1}{8}$ to $\frac{3}{16}$ inch thick.

In the middle of the table below the top a horseshoe magnet is arranged vertically.

One end of the wire of this magnet communicates with one of the poles of the battery, and the other with a flat metallic ring fastened to the upper part of the table making

the lid; below this metallic ring, and at a little distance, is a toothed ring F joined to the other pole of the battery. Pressing lightly on the table causes the lid to bend, the flat ring touches the toothed one and closes the circuit of the battery on the magnet which attracts its armature and produces a dull knock; lifting the hand, the lid resumes its original position, breaks the circuit again and produces another knock.

Passing the hand lightly over the table the lid is successively bent over a part of the circumference, makes and breaks take place on a number of the teeth and the distinct raps give place to a rumbling sound, clear or dull as required by the medium interrogating the spirits. As the table itself contains the whole mechanism it may be moved about without the trick being suspected.

The table may also be worked from a distance by using conductors passing through the feet under the carpet of the room, communicating with a battery the circuit of which is closed by a confederate in an adjoining room at opportune intervals.

Finally, a small telephone receiver may be substituted for the electro-magnet, and a micro-telephonic system for the ordinary battery, by which the spirit-rappings may be transformed into speaking voices. With a little practice it will be easy for the confederate to give messages from the spirits in a sepulchral voice, thereby adding to the illusion.

Fig. 137 shows an amusing device for the decoration of a room; it represents insects resting on a plant which is no sooner moved than their wings begin to move as if they were going to fly away. These insects are animated by a Leclanché battery hidden in the flower-pot. The insect itself is nothing more than a mechanism similar to that of an ordinary bell. The body of the insect forms the core of a straight electro-magnet *c* carrying a light return wire on its upper part, before which a small iron disc *b* is placed, making the head of the animal. The head is fixed to a spring like the armature of an ordinary bell, and works the wings, giving them a flapping motion when it is attracted and repelled alternately by the electro-magnet; the interruptions of the current are caused by means of a small tremble arrangement, the action

of which will be easily understood by reference to the drawing on the left of Fig. 137. The current reaches the electro-magnet by a fine copper wire hidden in the foliage, and is joined to the positive pole of the battery, the negative pole of which is in relation with the bottom of the pot.

FIG. 137.

The wire to the trembler of each insect runs to the bottom of the pot, but without touching it; a drop of mercury is on the bottom of the pot and rolling about freely. If, therefore, the pot be moved, the mercury rolling over the bottom by successively closing the circuit of the different insects sets them in motion until the pot is replaced and the mercury is again stationary.

Amusing Physical Experiment with an Induction Balance.—It is easy to be a very good conjurer if one is a good electrician, by pressing into the service of the art

the numerous resources of the science. The following is an example which makes use of one of the most remarkable discoveries of modern times, viz. the induction balance of Professor Hughes. This apparatus lends itself to a very curious and amusing trick which will doubtless be of interest to our readers.

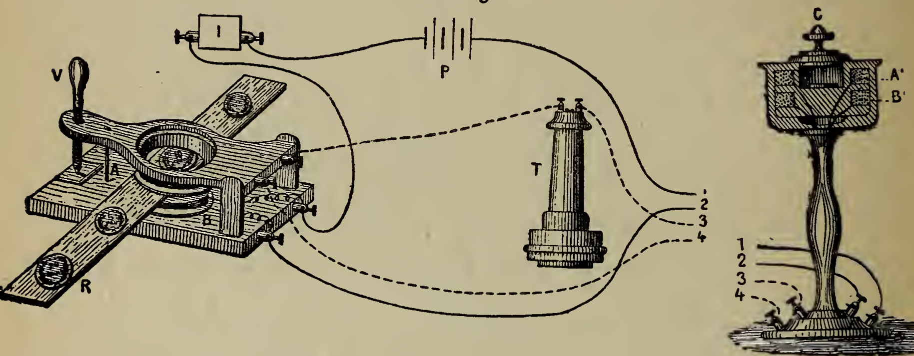
The experiment consists in guessing the value and nature of a piece of money, placed at a distance in a wooden box closed by a lid, without touching the case or even going near it.

The apparatus is in two parts, one of which is behind the scenes, and is shown on the left of the figure, the other is an ornamental wooden box, shown on the right of the figure, into which the piece of money whose value is to be guessed is placed. Four wires twisted together join the two parts. It is hardly necessary to say that if it is desired to perform the trick in a thorough and complete style, the conductors should be hidden and the terminals dispensed with by using contacts in the bottom of the stand. The case may also be suspended from the ceiling of a room as in the well-known trick of the magic drummer.

The apparatus, Fig. 138, consists essentially of four coils, A A′ B B′; the two coils B B′ are connected in series by the conductors 1, 2; the circuit is completed by a battery P and any contact-breaking apparatus I, for example a clockwork sending interrupted currents from the battery P into the two coils B B′; the two coils A A′ are also in series with one another by the conductors 3, 4, and a telephone T is introduced into the circuit. The battery therefore sends interrupted currents into the coils B B′, which develop induced currents in the coils A A′, but the winding of the coils is such that the action of A on B balances the action of B′ on A′ if the coils are quite equal and placed at equal distances apart. As in practice it is impossible to realise these conditions, the coil A is placed on a movable support and the distance is regulated by means of the screw V. When the induced currents are perfectly balanced the telephone T in the circuit of A A′ remains silent.

When under these conditions a piece of money is put into the box C, the balance is disturbed, so that in the telephone will be heard the click of the interruptions caused by the clockwork in the battery circuit.

FIG. 138.



In order to obtain silence an identical piece of money must be placed between the coils A and B. In practice a collection of the different coins of the realm may be stuck on one, two, or three flat wooden rulers, which are slipped between the coils quickly, stopping at each coin for an instant until the telephone is silenced, when the piece placed at that moment between the coils is the same as that in the box. If no coin in the collection silences the telephone, it is owing to the piece of money in the box being a foreign coin, or it is bad money.

This is in detail the curious trick which may be performed by the induction balance, an apparatus which by its nature touches on the highest theories of molecular physics.

Electric Toys.

Electricity lends itself to a number of curious, instructive, and amusing experiments, and an entire volume would not be sufficient to enumerate them all. We will content ourselves with describing a few of the simplest and easiest.

A Simple Electric Machine.—We will first of all

construct at little expense an electric machine capable of giving sparks three-quarters of an inch long.

A sheet of strong paper and of large size is used for this. Rub it well with the dry hand or some woollen fabric until it adheres to the table. A bunch of keys is then placed in the middle of the sheet, which is lifted by two corners. If at this moment any one brings the finger near the bunch of keys a brilliant spark is emitted, the finer and larger the dryer the weather and the more often the paper has been rubbed and heated.

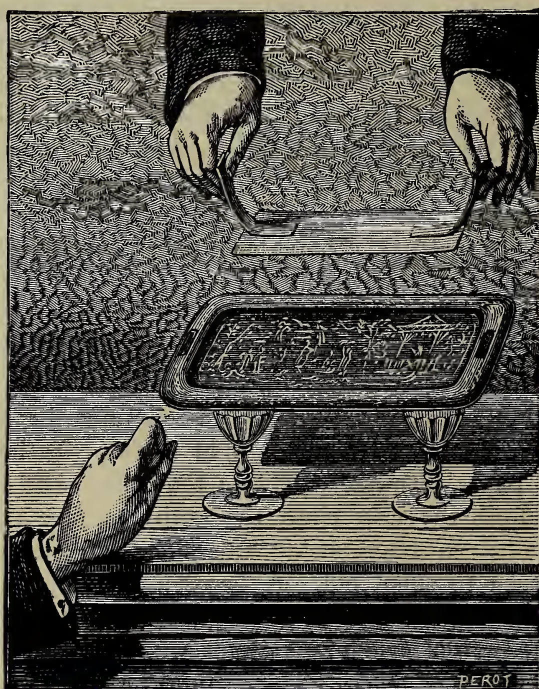
Ordinary paper, foolscap for example, well heated and dried, acquires electric properties when rubbed sharply; it will be felt to crackle in the hand under the influence of a multitude of small discharges slightly luminous in the dark. Electrified paper will adhere to walls. Wideman found that the electric properties of paper may be considerably increased by submitting it to previous treatment; if ordinary unglazed paper be plunged into a mixture of equal parts of nitric and sulphuric acid, then well washed with plenty of water and dried, it becomes extremely electric. If it is placed on a wooden table, or better still, on a wax cloth, and rubbed with the hand, it soon attracts all light bodies—feathers, small pieces of paper, pith-balls, &c. In the dark, when the paper is taken from the wax cloth the entire surface shines like phosphorus; on approaching the finger an electric spark will be seen to shoot out. A Leyden jar may be charged with this paper, which becomes a regular electrophorus, and in fact all the ordinary experiments with electric sparks and discharges may be made. This paper when rubbed gives out the characteristic odour of ozone. It keeps its curious properties for a long time, and when weakened it is sufficient to slightly heat it to restore all its energy. It will be seen that for a few pence an electric machine may be obtained sufficient to demonstrate all the electric phenomena.

An Economical Electrophorus.—Take a lacquered iron tea-tray, 12 to 16 inches long; cut a sheet of stout packing-paper to such a size that it will easily lie on the flat part of the tray. Two strips of paper are fixed by means of

sealing-wax to each end of the sheet to lift it by when placed on the tray. The tea-tray is then placed on two tumblers, to support and insulate it.

The sheet of paper must then be well heated over a very bright fire or stove till it becomes well dried and as hot as possible. This done, it is placed quickly, to prevent its

FIG. 139.



cooling, on a wooden table, and rubbed sharply with a hard and very dry clothes-brush. It is then placed on the tray; the tray is touched with the finger and the paper lifted up. If at this moment any one brings his finger near the tray a visible spark will pass, Fig. 139. The paper may then be replaced on the tray, and touching the edge a second time and relifting the paper, a second spark will be drawn out, and so on seven or eight times.

To make an extemporary Leyden jar, take a glass tumbler filled with shot, plant in the middle of the shot a teaspoon, and if everything be thoroughly dry we have an excellent Leyden jar. To charge it we work our electrophorus as just explained. While one operator touches the

FIG. 140.

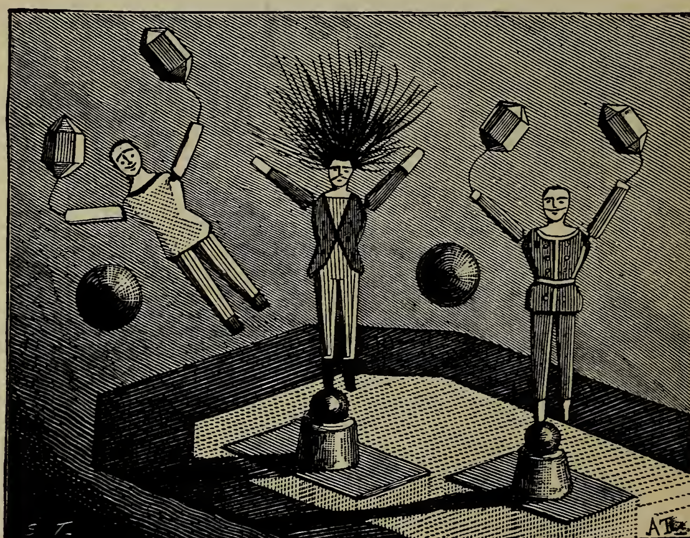
edge of the tray and lifts the paper, another person, holding the glass tumbler by the bottom, brings it to the tray, so that the spark takes place between it and the spoon. The Leyden jar is thus charged by means of successive sparks; a small discharge may then be obtained as shown in Fig. 140.

Pfeiffer's Electrophorus.—A number of instructive and amusing experiments may be effected with this. It consists in principle, Fig. 141, of a thin sheet of ebonite, 1 millimetre thick, 6 inches broad, and 8 inches long.

The wooden disc covered with brass of the classic electrophorus is replaced by a small brass sheet of the size of a playing card, fixed on to one of the sides of the ebonite.

This ebonite electrophorus produces electricity with remarkable facility. It is placed flat on a wooden table, rubbed successively on both sides with the open hand; if it is lifted in the left hand and the right hand brought near to the brass foil, a spark half an inch long will be obtained.

FIG. 141.



The ebonite electrophorus is completed by a number of small accessories consisting of small pith figures enabling the phenomena of electric attraction and repulsion to be demonstrated in a most amusing way.

Electrify the ebonite plate, place on the sheet of brass foil any of the small figures, and lift the plate to insulate it from its support. Here is a small mannikin lifting its arms to heaven, or this one the silken hair of which stands on end, and the third, lighter than the others, leaps away like a clown and escapes from the electric influence, together with the two small pith-balls which were placed alongside it. We have

grouped the three mannikins in a single drawing, but they are generally worked singly.

Magnetic Toy.—Magnetism also lends itself to a number of amusing experiments owing to its action at a distance and through most bodies. Every one has been amused as a child

FIG. 142.

by making a needle stand on end by means of a magnet placed over it sufficiently distant from the needle to keep it vertical, but not close enough to lift it altogether, or by making a pen run about a table without apparent reason by manœuvring a magnet underneath the table. This experiment, revived in a more elaborate style, is represented in Fig. 142.

The scene represents a circus with painted decorations and track formed of a piece of yellow coloured cardboard.

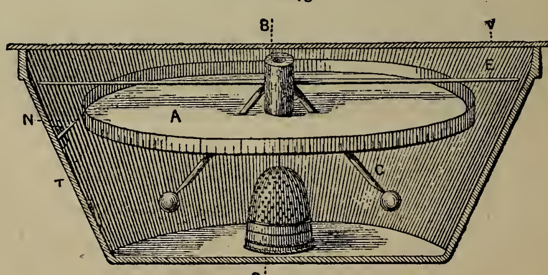
In the middle of the track small figures are placed on

wooden bases. As shown in the drawing these may consist of three musicians and one master of the ring. Toward the circumference of the circus other small figures are placed, representing a horse mounted by a lady rider, a car drawn by a sorrel horse, a horse at liberty, &c. By turning the handle on the base of the toy, the band strikes up and at the same time, the horse starts by itself and runs round the circular track. The horse is taken away and replaced by the harnessed horse. Turn the handle, and as the music sounds, the car becomes animated like the horse and spins round the master of the ring and the musicians, who do not move.

The explanation is very simple : the handle moves a magnet hidden in the case which serves as support to the small circus ; this handle, while working the mechanism of the music, at the same time turns the magnet round an axis in the centre of the circus. The small figures which move round the ring are mounted on small soft iron bases, and are very light, and the surface of the cardboard being highly polished, the magnet is powerful enough to overcome the friction and so drag these light objects with it.

An Economical Compass.—The 'Magasin Pittoresque' describes a simple and economical compass. It says: "Take a small cork, Fig. 143, and pass an ordinary knitting

FIG. 143.



needle through it which has been magnetised by gently rubbing it in one direction on one of the small horseshoe magnets given to children. When the needle E is passed through the cork, a sewing needle or a pin is stuck in one of

its ends, and the point lodged in one of the holes on the top of a thimble. To balance it a match C is run in on each side

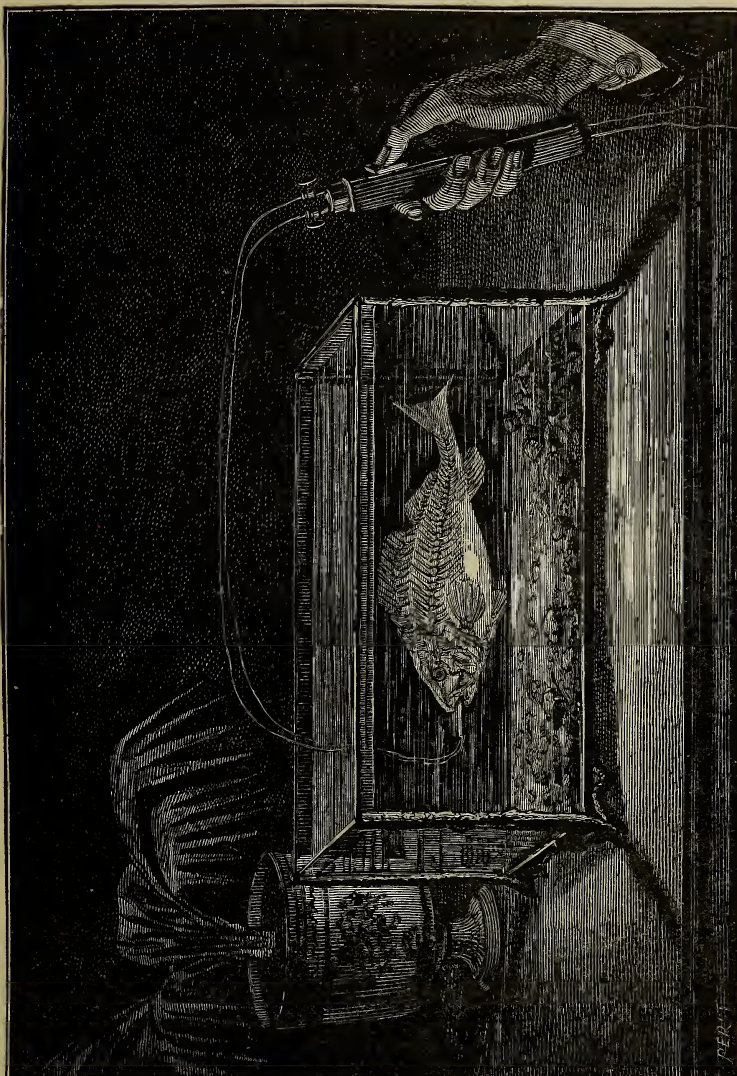


FIG 144.

of the cork as shown in the drawing, and wax melted on to the end of each match until the whole is properly balanced.

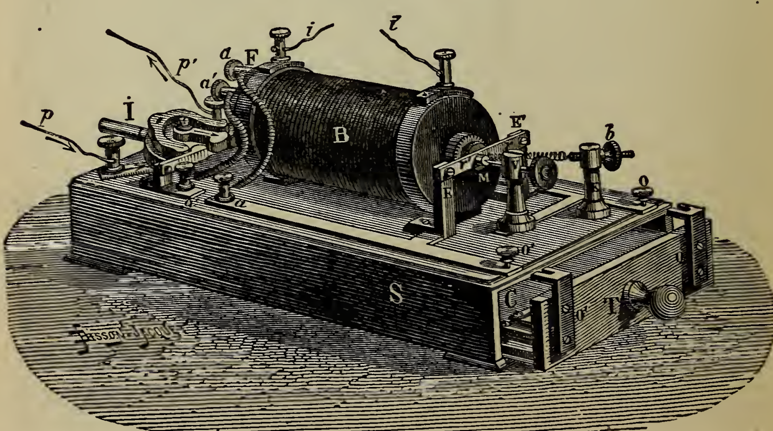
As it is very important with so sensitive an instrument to avoid agitation by air, the thimble is placed on the bottom of an ordinary earthenware basin B D T and closed with a pane of glass V. To graduate the compass, a circle is described with a pair of compasses on stout paper, and the points and degrees marked off. This is then fixed under the needle, the north end of the card coinciding with the north-seeking pole of the needle.

If a fine sewing needle be magnetised and smeared with tallow it will float on water, thus making a very simple compass.

Luminous Fish.—Fig. 144 shows the effect of an experiment of M. Trouvé, in which a fish is caused to swallow a tiny incandescent lamp which is then lighted, showing every bone in its body. These lamps are now much used by surgeons and dentists for lighting up the cavities of the body. They are especially useful to dentists, who are able to have a powerful light thrown through the teeth rendering them transparent, when the slightest decay becomes visible.

The Induction Coil.—This is used to modify the qualities of the electric current and generally to increase the

FIG. 145.



tension or E.M.F. at the expense of the current ; or as it is sometimes wrongly stated, it transforms dynamic electricity

into static electricity. We most strongly protest against this definition which tends to the idea of two different electricities, while really they are only modifications of one and the same phenomenon.

However, with the Ruhmkorff coil, a number of very amusing, interesting, and instructive experiments may be made. Fig. 145 shows a very convenient form of this instrument, in which all the connections are visible, enabling the course of the current to be traced out; the secondary coil is movable and enables the power of the induced current to be varied at will and the condenser may be used or not, as required, which enables its action on the nature and power of the spark to be studied.

Caricatures on Electricity.—We cannot better close the chapter devoted to electric recreations than by a reference to the many caricatures relating to electricity which have appeared.

The kind of electric furore which attacked London in 1881 and 1882, in consequence of the brilliant results obtained from the first attempts at public and industrial electric lighting, gave an opportunity to the caricaturists to exercise their wit on this subject.

From the numerous caricatures which appeared at that time we will reproduce two.

The first appeared in *Punch* on the 25th June, 1881, at the time when the Faure accumulator appeared in England. King Coal and King Steam anxiously watch the new arrival, and ask, Fig. 146, "What will he grow to?" King Coal is particularly put out and gives the baby a look boding it no good. It is now well known that this anxiety was altogether needless, as, to store electrical energy, it is generally necessary to consume coal.

The second caricature, Fig. 147, appeared in *The City* of the 4th November, 1882, and represents "The dream of a gas director." The artist endeavoured to picture the nightmares which haunt the brain of a gas company's director, thinking over the new inventions of electric lighting, which at that time were rapidly introduced in England by numerous

P 2

companies, some of which, from the first, were only ephemeral.

Our Director, before going to sleep, reads *The City*, and instead of finding the desired rest, electric lighting and the

FIG. 146.

various phases of its development and rapid progress pass before his eyes as a vision in the shape of promotors and inventors, while the gasometer disappears in the darkness of the night.

Perpetual Motion by means of Electricity.—As might have been expected, electricity has been pressed into

the service of inventors of a certain class who seriously propose projects involving perpetual motion.

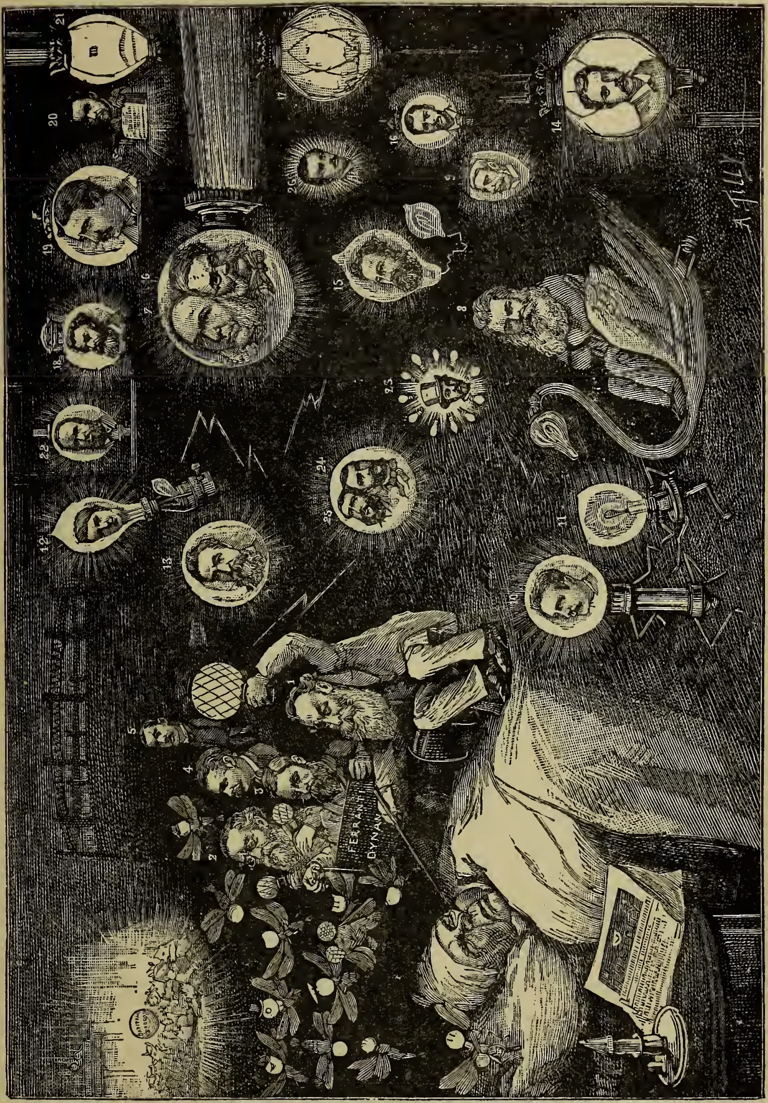


Fig. 147.

An inventor (save the mark) proposed as the sole and only true solution of domestic electric lighting, a common clock-

work arrangement which was to work a dynamo producing a powerful current, of which it would be sufficient to shunt off a portion to rewind the clockwork. Nothing simpler!

Another actually proposed a no less infallible system of working tramways by using the excess of power produced during rotation (?) of the wheels to charge accumulators to be used at starting!

Quite recently, too, an engineer, editor of an industrial publication, seriously proposed a carbonic acid motor, in which the cooling produced by the expansion of the gas was to be counterbalanced by platinum spirals, heated by an electric current furnished by a small dynamo run by the motor itself (*sic*)?

It seems almost a dream to read in 1884 of such absurdities.

CHAPTER XIII.

VARIOUS APPLICATIONS—WORKSHOP OF THE ELECTRICIAN.

A WHOLE book would be required to review entirely all the various applications of which electricity is susceptible, and which could not be classified under any of the foregoing headings. We can here only refer to a very few taken haphazard.

Physiological Actions of the Current—Medical Applications.—Electro-therapeutics are becoming every day more important in medicine, and in spite of the opinions so divergent which still divide practitioners, it may be hoped that before long, thanks to the introduction of precise methods and measuring apparatus into medical practice, the doses of electricity will cease to be *quack*, and become scientific and rational. However, the results already obtained are sufficiently important to justify their introduction into daily practice.

Electricity is employed in medical practice under two forms: (1) continuous current; (2) alternating or induced current.

Continuous currents are always produced by means of small batteries easy to move about and to renew; sulphate of copper or Leclanché batteries are very suitable for this application. They are coupled in tension by means of a commutator in the case holding them; a varying number may at will be taken according to the effects to be obtained, the nature of the disease, the parts to be affected, &c.

Alternating currents are obtained by means of a small

Clarke machine, or an induction coil. With the first the power is modified by changing the speed, or by masking the magnet more or less. With the induction coil either the number of elements in the primary circuit may be varied, or the number of induced currents produced in a given time may be altered by regulating the speed of the trembler ; or, finally, the quantity of electricity developed at each discharge may be varied by altering the distance between the primary and secondary coils.

It will be understood, so great a number of variable factors being given, that the logical and rational application of electricity to therapeutics becomes a complex, delicate, and difficult question, and the intervention of a practitioner is required to apply it judiciously.

Together with the direct use of the current, electricity is used in an indirect manner in a number of cases, such, for instance, as to localise the position of a bullet, the lighting of dark cavities, cauterisation, &c. ; but the study of these applications cannot be gone into here.

The Training of Horses by Electricity.—Various means have been proposed to stop and master runaway or restive horses ; there is nothing more ingenious and efficacious than that devised by Defoy, and of which M. Bella, manager of the French Omnibus Company, has had occasion to appreciate the advantages. This question cannot fail to be of interest to those fond of horses. The apparatus is simply a Clarke machine inclosed in a case, which may be placed convenient to the hand of the rider or driver. The reins contain conducting wires connected to the bit and to the magneto-electric apparatus. By turning the handle a current is sent through the mouth of the horse, giving it such a surprise that it stops and remains quiet. By coupling the action of the electricity with gentleness and petting the most dangerous horse will be rapidly mastered.

M. Bella reports that M. Defoy tried his apparatus in his presence at the yard of the General Omnibus Company (French), where the worst tempered and most dangerous horses were assembled. A gelding, very difficult to shoe,

was brought to the forge, where it showed excessive temper, but when supplied with the electric *persuader*, it, at the end of a few minutes, allowed its neck and back to be patted, then its limbs, and finally, the hind feet were lifted, always the most difficult to approach and to lift up. The shoe was hammered without the horse again becoming rebellious, says M. Bella, and its shoes were changed without being shackled, and without recommencing its dangerous defences.

The Director of the Paris Cab Company also certified to the efficiency of this process: "The experiment," says M. Camille in a report before us, "was tried on several horses which up till then it was impossible to shoe, all, without exception, being tamed by the apparatus. One horse about to be shod, rolled about on the ground, kicking and struggling against everything, and nothing could subdue it. I had recourse to M. Defoy's apparatus; at the first trial the feet of the restive horse were, to my astonishment, lifted without great difficulty; at the second trial it was as easy to shoe it as if it had never offered any opposition; the animal was conquered."

M. Defoy drove a dangerous horse before us, which he stopped instantaneously after being set galloping, by turning the handle of a Clarke apparatus fixed under the seat of the vehicle, Fig. 148. It is important to state that the result is not due to a violent shock; the electric current is not strong enough to galvanise or stupefy the animal; it rather produces astonishment and the disagreeable but not painful sensation of electric pricking. We ourselves have very easily borne the current of the magneto-electric apparatus used by M. Defoy. There is nothing in the process on a par with the barbarous methods sometimes used to tame horses by force or violence, which tire them out, excite them, and make them wild and vindictive.

We will add that M. Defoy completes the electric bit with an electric stick not less ingenious than the first apparatus. This is a whip containing two insulated conductors, ending in two points at right angles to the end of the stick, and are, as in the case of the bit, connected to a magneto-

electric apparatus. A horse in the habit of rearing may, at the moment it attempts to do so, be stopped by giving it the

Fig. 148.

spur and at the same time applying the electric stick to the top of the neck. Under the influence of the electric current

it at once starts forward with head down. The same effect may be produced on a shying horse, by applying the current to its jaw on the side towards which it attempts to shy, when it will at once be stopped. By means of an electric stick M. Defoy makes a horse obey him in a few seconds in a truly marvellous manner.

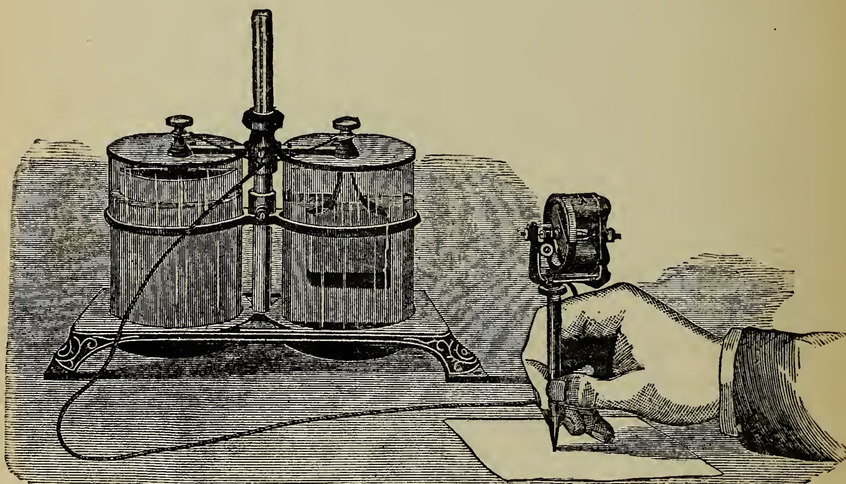
Edison's Electric Pen.—The electric pen is an apparatus by which marks are made on ordinary paper—not a continuous coloured mark as with ordinary pens and pencils, but a broken mark, formed by a great number of small holes pierced through the paper. These holes are made by a very fine steel point, which alternately goes in and out of a tube held in the hand, and which much resembles a metal pencil. This point is worked backwards and forwards very rapidly; it makes 180 strokes a second when doing no work. Each time it passes out of the case barely enough to be visible, but quite enough to pierce the paper. The writing is not so quick as with ordinary pens, but nearly as quick as that of a writer who takes time to shape his letters well.

The alternating motion is given to the pen by a small electro-motor, very ingenious and simple, which is placed above the penholder, as shown by Fig. 149. The point is at the lower end of a rod which traverses the penholder, and which at its upper part ends in a fork pressing an excentric mounted on the axis of the motor. This excentric has three cams, and therefore sixty revolutions of the axis per second produce the 180 strokes just mentioned. This axis carries a soft iron plate acting as movable armature to a fixed electric magnet, before which it revolves rapidly, by means of a very simple commutator, which breaks the current twice per revolution. A fly-wheel, relatively heavy, surrounds this armature, which is a diameter to it, and it serves to give great regularity and steadiness to the motion of the axis.

The electric current which gives life to this small apparatus is furnished by a bichromate of potash battery of two elements suitably arranged. The lids of the two cells are of ebonite plates, joined to a metallic central piece which slides

on a vertical rod; the lids carry the two electrodes, carbon and zinc. When the pen is used, the electrodes are plunged into the liquids. When the writing is finished the central piece is lifted up and hooked to the upper part of the sliding

FIG. 149.



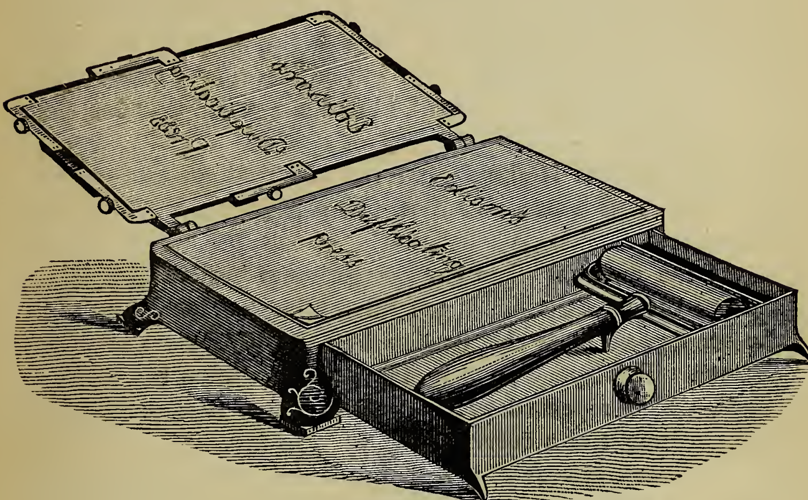
rod, and then the electrodes are kept from contact with the liquids, and consequently no zinc is uselessly consumed.

Thanks to this precaution, the battery will work for four days without any maintenance whatever, that is to say, without renewing the liquid, and the zinc may work for several weeks.

By means of the electric pen, writing is obtained, formed by a number of small holes close together. This writing is very difficult to read by reflection, that is to say in the usual way for ordinary writing; it is more readable by transparency, but either way would be useless in practice. But this perforated paper must be treated as a negative, by means of which a great number of positive proofs may be obtained. To obtain these copies the press represented in Fig. 150 is used. The negative is placed on the lid shown on the left; it is kept in position all round by springs easy to manipulate.

On the body of the press a sheet of white paper is placed, and the lid is put over it; the negative is applied to the white paper. By means of the roller shown on the right, ink is spread over the negative, which penetrates through all the

FIG. 150.



holes to the sheet of white paper below. When the lid is relifted the proof is obtained. This copy has a peculiar appearance; the writing has neither thick down nor light up strokes. To be readable it should have been clearly written. However, with some use and some very simple artifices all kinds of designs are obtained; music may be copied with the whites and blacks perfectly reproduced. The same negative may be used to produce a great number of proofs; it is said up to a thousand and more may be obtained.

Persons used to the work will print six copies per minute. Of course like all other manual labour, this operation is not learned without a little study and some trouble, but there is nothing difficult about it.

Bellet and Hallez d'Arros' Voltaic Pencil.—This apparatus was to obtain the same results and to satisfy the

same wants as Edison's electric pen, but it differs essentially from it by the means employed.

It is known that the spark of the electric machine or the induction coil flashing between two metallic points or between a metal point and a conducting body, is susceptible of piercing cardboard and more so, paper. Let us suppose, between such a point and a conductor, we have a series of electric sparks flashing almost continuously, while between these bodies a sheet of paper is moved. This will be pierced by holes : the closer together the more sparks there are, and the slower the paper passes.

The principle is simple, but the practical realisation was not effected without difficulties, the principal one being the following :—

At the moment when the draughtsman brought the point near to the paper, a spark several millimetres long flies out, the consequence of the tension between the two opposite charges. This spark gave to the person holding the point a shock, which repeated every moment made it impossible to trace a straight or a curved line.

The spark besides was rarely insulated, several sparks were created at the same time, piercing the paper in several places round the point wanted. Therefore no clean and precise mark could be obtained. Finally, in order not to have the holes too far apart, without being obliged to slacken the speed of the pencil, it was necessary that the sparks were far more numerous than those produced by ordinary induction coils.

Bellet and d'Arros have succeeded in overcoming these difficulties. The induced current passes through the point and at the same time part goes through a shunt in a measure and within limits which may be regulated at will, the sparks between the point and the metallic plate being thus reduced so that they just suffice to pierce, cut, or destroy the paper where they are produced without giving appreciable shocks.

The paper used, which must be very fine, is previously soaked in a solution of sea salt and then dried. This simple operation prevents multiple sparking and enables absolutely

clean marks to be obtained. The contact-breaker, trembler, and the bobbin were also modified in form. Fig. 151 shows

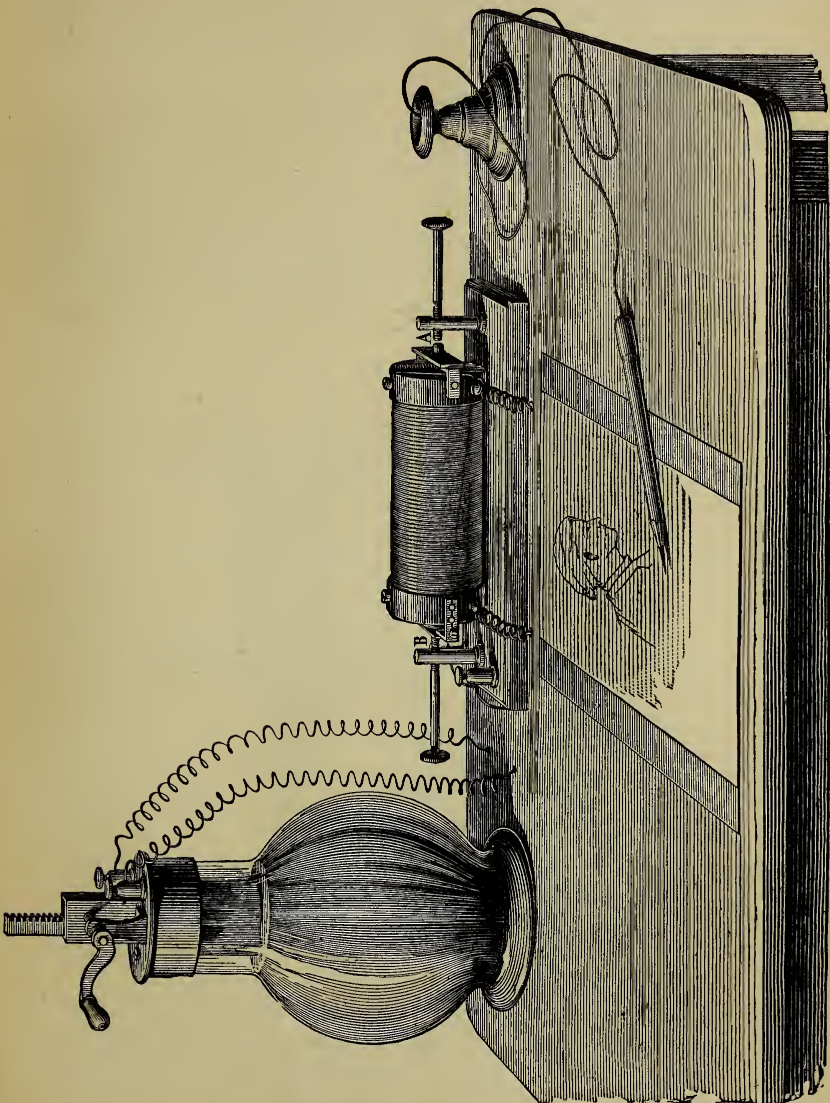


Fig. 151.

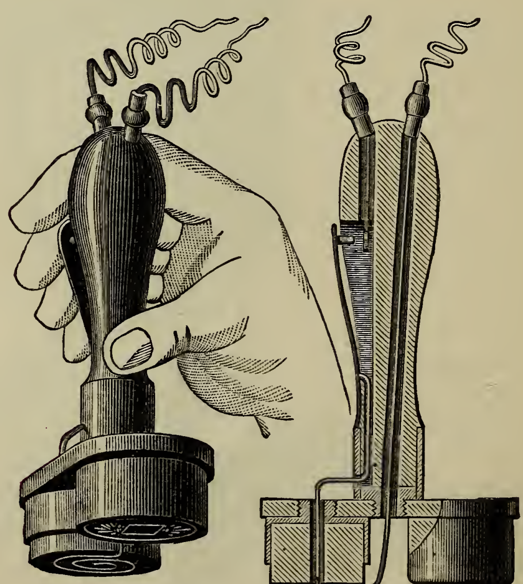
the principal arrangement of the voltaic pencil; it is similar in appearance to an ordinary pencil, the wood of which serves as

insulator, and the lead as conductor. A flexible wire covered with silk joins the pencil to the secondary wire of the coil.

The desk supports the metallic plate on which the sheet of paper is placed and holds the printing arrangement similar to that of Edison's pen.

Electric Stamper.—This apparatus is intended to replace the ordinary damp stamps used to obliterate stamps, cheques, invoices, &c. At the lower part of the apparatus is a thin platinum wire shaped so as to make a design or an initial. This is the part applied to the surface of the stamp to be cancelled. The platinum wire is in communication with a battery. The circuit is closed by pressing a spring with

FIG. 152.



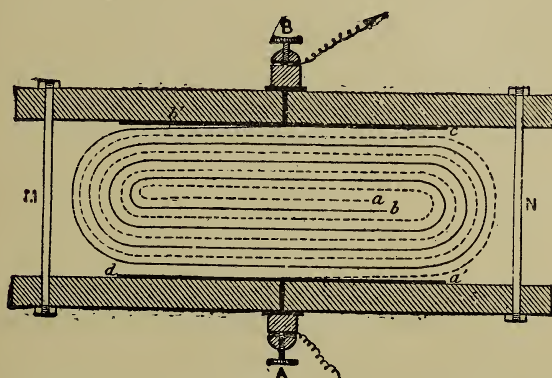
the finger, as shown in Fig. 152. The platinum glows and the paper to which it is applied is carbonised by the heat and bears the trace of an imprint absolutely ineffaceable. This ingenious system may not alone be used by the post office, but also by merchants who have to cancel a great number of stamps.

Photophonic Experiments.—Selenium possesses the singular and curious property of changing its resistance with the intensity of the light which falls on its surface; Graham Bell's photophone is based on this action.

A selenium cell easy of construction and sufficient to demonstrate the principles of Bell's discovery may be made for experimental purposes in the form shown in Fig. 153, which gives one of these cells in actual size.

To construct it, take two brass strips *a* and *b*, about one-tenth of a millimetre thick, and one centimetre wide. They are separated by two strips of parchment paper which insulate

FIG. 153.



them, and the four strips are rolled into a spiral, as shown in the figure, where one of the brass strips is represented by a full line, the second by a dotted line, and the paper by the blank space separating them. The block so formed is placed between two brass plates *c* and *d* in contact respectively with the ends *a'* and *b'* of the metallic strips; the whole is strongly pressed between two hard pieces of wood by two tie-pieces M and N. Two terminals A and B, in metallic communication with the plates *c* and *d*, join the element to the circuit in which it is to be included. One side is then filed smooth and carefully polished with emery paper. After having thus polished the block, and having tested with a

sensitive galvanometer the absence of metallic communication, the polished surface is covered with selenium in the following manner :—

The apparatus is heated in a sand-bath, or by placing it over a thick copper plate heated by the flame of a Bunsen burner up to a temperature at which a selenium pencil pressed on the top will melt; the pencil is then worked along the surface, so as to cover it with as slight a coat as possible. By not allowing the temperature to get above this point, the selenium takes the slaty tint characteristic of the state in which it is most sensitive to light; when cool it is ready to act. To preserve the surface, it may be protected by a thin mica plate, or covered with a coat of shellac varnish laid on hot. When the apparatus becomes deteriorated, it is sufficient to file up the surface, polish it, and put fresh selenium on to recondition it. The resistances of these cells vary greatly with the sizes, nature of the selenium, mode of preparation, &c. To obtain good results, about ten Leclanché cells in tension and a very high resistance telephone are required, that is to say, one, the fine wire of which makes a great number of turns round the magnetised cone.

Private Electric Laboratories.—According to taste, means, and the sum to be spent upon it, electricity takes a more or less important position in the house of an amateur. With some electricity is everything, with others nothing. A middle course between these two extremes should be kept so as not to become either an electromaniac or an electrophobe. Some eminent scientists have expended endless time and money in perfecting their laboratories, foremost, perhaps, among them being that of Mr. Warren de la Rue, which represents a fortune in itself. M. G. Planté's laboratory, of which Fig. 154 reproduces a part, is also worthy of remark. Here 800 small secondary cells are to be seen, being those used by him in his experiments on high tension currents.

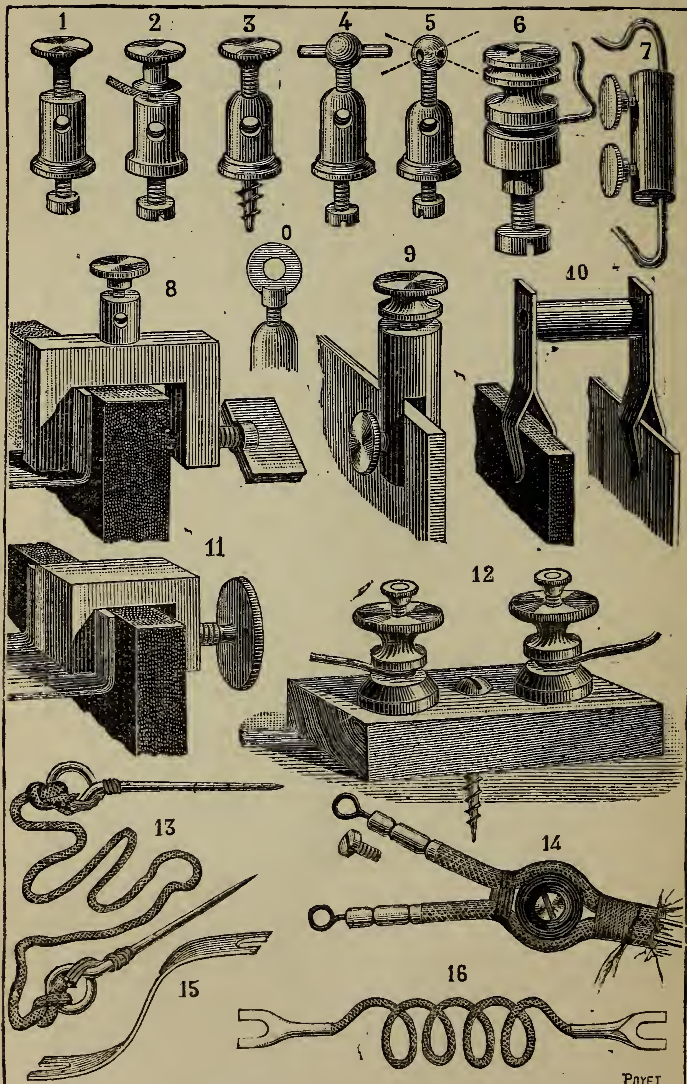
The Amateur's Workshop.—The most necessary tools for the amateur are those for working in wood and metal, and he should accustom himself to the handling of these with some amount of skill, to enable him to construct for himself,

in a more or less rough fashion, the elementary parts of apparatus. At most manufactories he will be able to obtain

Fig. 154.

parts ready made, only requiring finishing up and putting together, but whatever tools he may possess, it will, for

FIG. 155.



example, be waste of time for any one to make their own terminals, and cover their own wire. It may, on the other hand, however, be advantageous to wind for himself any electro-magnets he may require, so as to be sure of the length of wire wrapped on and its resistance. Small means must be content with a box of tools more or less complete, but containing the essentials for working in wood and metal ; whatever may be wanting must be made up for by patience and careful contriving. Those who are more fortunate may be able to set up a small workshop containing a carpenter's bench, a vice, and a small foot lathe with the necessary tools.

We do not, however, propose in this book to go into the full details of workshop construction, and we would refer our readers to any of the known manuals on the special subject, but for their guidance we give in Fig. 155 some sketches of ordinary terminals, connections, &c., which will be required, no matter what kind of work they may undertake, and the uses of the various parts will be easily understood from an inspection of the figures.

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